EVALUATION OF THE AIR FORCE'S ALTERNATIVE FUEL VEHICLE PROGRAM IN COMPLYING WITH EXECUTIVE ORDER 13149

THESIS

Janette D. Ketchum, 1st Lieutenant, USAF

AFIT/GLM/ENS/01M-13

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GLM/ENS/01M-13

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Janette D. Ketchum, B.A.

1st Lieutenant, USAF

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Janette D. Ketchum, B.A.
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Approved:

William A. Cunningham (Chairman)	1 Mar 01 date
Jeffrey N. Rumrill (Member)	1 Mar 01 date
Peter T. LaPuma (Member)	1 Mar 01 date

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Janette D. Ketchum

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Abstract

The Air Force must comply with Executive Order (E.O.) 13149, which includes cutting its vehicle fleet's petroleum fuel usage 20 percent by 2005. This thesis examines the Air Force's current alternative fuel vehicle (AFV) program, which is centered around the acquisition and use of compressed natural gas (CNG) vehicles, to determine whether it has been effective, and how the AFV program should be tailored to contribute to the Air Force's efforts to comply with E.O. 13149. The results of the study discussed here suggest ways in which the Air Force's AFV program can be modified to increase the program's impact on petroleum consumption. Although analysis shows that full compliance by all federal agencies will decrease the annual amount of oil imported to the United States by less than one percent, the Air Force must meet E.O.13149 requirements. The Air Force has effectively managed its CNG vehicle fleet by assigning a vast majority of CNG vehicles to units with access to CNG fueling infrastructure, but usage of CNG vehicles' in their CNG capacity must be increased if the AFV program is to contribute to the Air Force's effort to cut petroleum usage.

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I. Introduction

General Issue

A steady increase in environmental requirements and a steady decrease in budgetary funds over the past decade placed the Air Force in a precarious position. Senior leadership has been tasked to strike a balance between complying with costly environmental standards and running a high operations tempo Air Force on a shrinking budget.

Numerous environmental requirements are prevalent among Air Force organizations with an industrial base such as Civil Engineering, Aircraft Maintenance, and Transportation. Because the Air Force maintains a federal vehicle fleet, it must comply with two recently published Executive Orders (E.O.s), both of which are meant to promote a "greening of the government" (White House, 1996:1). President Clinton issued E.O. 13031, "Federal Alternative Fueled Vehicle Leadership", in 1996 and E.O. 13149, "Greening the Government Through Federal Fleet and Transportation Efficiency" in 2000 to provide leadership by the federal government in the environmental arena, and to meet three underlying objectives. The first objective is to reduce the country's dependence on foreign resources such as oil. As demonstrated during the Gulf War, this is a national security issue. The United States (U.S) imports about half of the petroleum

that it uses. Estimates indicate that "Petroleum used in transportation alone exceeds total domestic production by 2 million barrels per day. This gap is growing, and is expected to reach nearly 6 million barrels per day by the year 2010…" (Pacific Northwest, 2000). The second objective is to use limited natural resources more effectively. The third objective is to help the environment by reducing air emissions through the use of cleaner burning fuels and more efficient vehicles such as Alternative Fuel Vehicles (AFVs). Both E.O. 13031 and E.O. 13149 stress the increased use of and alternative fuels in an effort to meet these three objectives. An AFV, "as defined by the Energy Policy Act, is any dedicated, flexible-fueled, or dual-fueled vehicle designed to operate on at least one alternative fuel" (Department of Energy, 2001). In order for a fuel to be deemed an alternative fuel by the Department of Energy (DOE), the fuel must meet two requirements. First, the fuel must be "substantially non-petroleum" (Air Force Center for Environmental Excellence, 2000a). Second, the fuel must yield "substantial energy security benefits and substantial environmental benefits" (Air Force Center for Environmental Excellence, 2000a). It should be noted, however, that the DOE does not count the "petroleum hybrids available today" as AFVs (Department of Energy, 2000a). Natural gas, either compressed or liquefied, alcohol fuels such as methanol and ethanol, liquefied petroleum gas, hydrogen, fuels derived from biological materials, and electricity are currently recognized as alternative fuels by DOE (Department of Energy, 2000c).

E.O. 13031, published in 1996, called for federal agencies to comply with the AFV acquisition requirements in the Energy Policy Act of 1992 (EPACT 1992). The AFV acquisition requirements, which are shown in Figure 1, were to be phased in from fiscal year (FY) 1996 through 1999 (White House, 1996:1). A recent Air Force

Environmental briefing showed the Air Force's progress in meet the acquisition requirements set in E.O. 13031. The Air Force was on track for years 1997 and

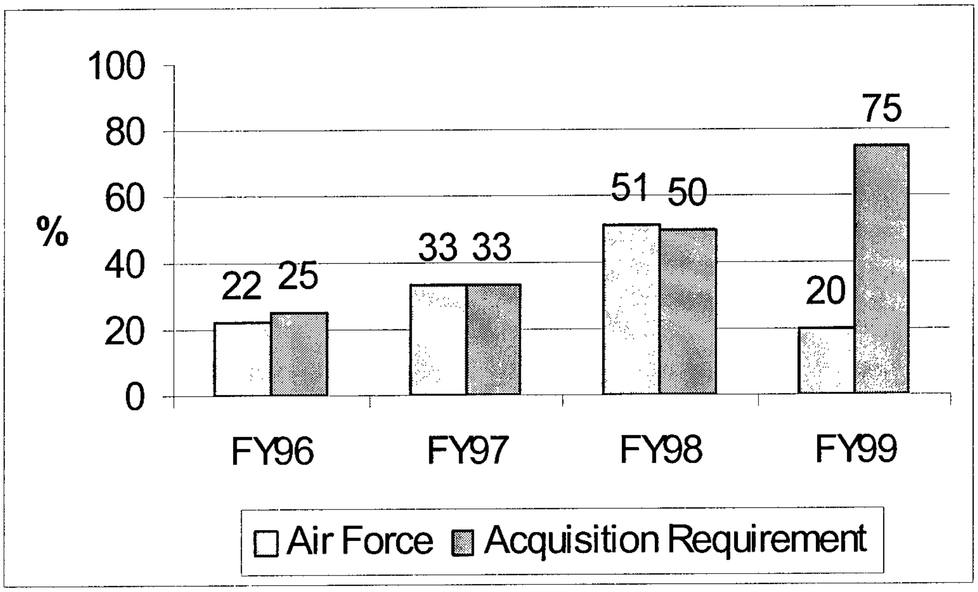

Figure 1. Air Force Alternative Fuel Vehicle Acquisition Compliance
(United States Air Force Environmental, 1999)

1998, but fell considerably short of the 75 percent acquisition requirement in 1999 (see Figure 1). The Air Force is not projected to meet the 75 percent AFV acquisition requirements by FY2000 according to Lieutenant Colonel Basile, a staff officer at Air Staff, Installations and Logistics, Transportation Vehicle Management (AF/ILTV) (Basile, 2000). The Air Force employs a variety of AFV types, but has concentrated on the acquisition of vehicles that use compressed natural gas (CNG), both bi-fuel, which can use CNG or gasoline, and dedicated, which can only use CNG. The term CNG vehicles will be used to describe the Air Force's fleet throughout this thesis when referring to the Air Force's fleet of both bi-fuel and dedicated CNG vehicles. In 1998, as

shown in Figure 2, CNG vehicles comprised 88 percent of the Air Force's AFV fleet. The Air Force's AFV policy throughout much of the 1990s had been driven, in large part, by requirements in EPACT 1992. The Air Force's AFV policy then shifted to meet E.O. 13031 requirements. Since E.O. 13031 has been replaced by E.O. 13149, the Air Force has shifted its focus on meeting E.O. 13149 requirements.

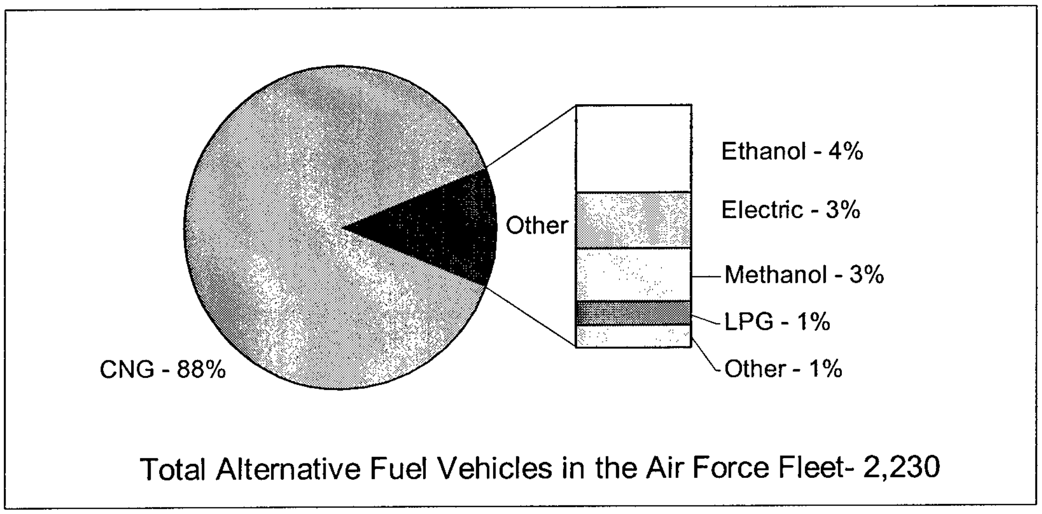

Figure 2. 1998 Air Force Alternative Fuel Vehicle Fleet
(FY1998 Federal Fleet Report, 2000)

E.O. 13149, "Greening the Government Through Federal Fleet and Transportation Efficiency", expressly requires that a federal agency, "shall reduce its entire vehicle fleet's annual petroleum consumption by at least 20 percent by the end of FY 2005, compared with FY 1999 petroleum consumption levels" (White House, 2000). In addition to this requirement, section 202(a) states that federal agencies are still required to comply with the AFV acquisition requirements that were established in EPACT 1992. The fact that AFVs are still being introduced to the general public and as such are not

widely available for commercial purchase makes them prohibitively expensive. As stated earlier, the Air Force has worked with a reduced budget in recent years while trying to meet environmental compliance requirements, and has been forced to prioritize the requirements and then decide on a compliance strategy. The Air Force's plan, submitted to the DOE in October 2000, summarizes Air Force strategies for complying with the requirements listed in E.O. 13149.

Specific Problem

The Air Force must comply with the requirements in EPACT 1992 and E.O. 13149 while working within a limited budget. Given the Air Force's current AFV policy, this thesis investigates how the Air Force's use of CNG vehicles can be focused towards complying with the E.O. 13149 requirement to cut petroleum fuel consumption 20 percent by 2005.

Research Objective and Question

The objective of this thesis research is to examine ways in which the Air Force AFV program can be tailored to contribute to the Air Force's efforts to comply with EPACT 1992 and E.O. 13149. The research question this thesis investigates is how should the Air Force modify its AFV program to increase the program's contribution to meeting E.O. 13149 requirements. To effectively answer the research question, the following investigative questions must be answered:

1. By how much will the country's dependence on foreign oil be reduced if E.O. 13149 is complied with?
2. What are the advantages and disadvantages of a CNG vehicle as compared to a gasoline vehicle for the Air Force?
3. Is the Air Force's current dispersion of CNG vehicles and infrastructure effective?
4. Will the Air Force's AFV policy produce expected results such as a reduction in emissions, an increase in alternative fuel consumption, and a reduction in petroleum fuel consumption?
5. Has the Air Force optimized its use of funds with its previous CNG acquisition policy?

Scope

When considering the option of acquiring additional AFVs or the increased use of alternative fuels this thesis will focus on CNG vehicles due to the concentration of CNG vehicles within the Air Force's fleet. The Air Force's use of CNG is viewed as a short-term solution to meeting fueling and regulatory requirements, due to the finite supply of CNG.

Summary

This chapter introduced EPACT 1992 and E.O. 13149, the requirements the Air Force must meet in maintaining its vehicle fleet, and explained the purpose and scope of this thesis.

II. Literature Review

Introduction

This chapter provides a review of the literature that is pertinent to analyzing the Air Force's AFV policy and the use of CNG vehicles to meet E.O. 13149 and EPACT 1992 requirements. E.O. 13149 and EPACT 1992 requirements, as well as the impetus behind them are addressed first. In addition to its requirements, a description of the approaches provided by the DOE for complying with E.O. 13149 is also presented. An overview of some of the more commonly available AFVs is then provided. Finally, a description of the Air Force's vehicle procurement process, the priority buy system, is given.

EPACT 1992

The EPACT 1992 was passed in part to implement national energy policy. The policy's main objective is geared towards improving our country's energy security. The intent of EPACT 1992 is to decrease our nation's dependence on foreign oil and to increase our nation's use of alternative fuels which are produced domestically (Department of Energy, 2000b). EPACT 1992 explains the use of alternative fuels in addition to putting forth the minimum AFV acquisition requirements for federal and state agencies (Office of Governmentwide Policy, 2000). Federal and state agencies must comply with the acquisition requirements in EPACT 1992 if three conditions exist. First, the federal or state agency must have a fleet of 50 or more light-duty vehicles. Second, at

least 20 of those vehicles must operate primarily in Metropolitan Statistical Areas (MSAs). An MSA is an area with a population of at least 250,000 per the 1980 United States Census (Department of Energy, 2000b). Third, there must be capability to centrally fuel the vehicles. Table 1 illustrates the acquisition requirements listed in EPACT 1992, and reiterated in E.O. 13149. Various types of vehicles are exempt under EPACT 1992, and include law enforcement, emergency, non-road vehicles, and those vehicles used for demonstrations, evaluations, and tests. Military tactical vehicles are also exempt.

Table 1. Air Force Alternative Fuel Vehicle Acquisition Requirements

Fiscal Year	**AFV Acquisition Requirement**
1996	25%
1997	33%
1998	50%
1999	75%
Thereafter	75%

(Air Force Center for Environmental Excellence, 2000a)

E.O. 13149

E.O. 13149, which instructs federal agencies with fleets of over 20 vehicles to cut their petroleum fuel consumption 20 percent from FY 1999 levels by 2005. When considering applicability, the major distinction between EPACT 1992 and E.O. 13149 is geography. Unlike EPACT 1992, E.O. 13149 applies to fleets of 20 or more vehicles

regardless of where they operate. In addition, E.O. 13149 also mandates that federal agencies reduce petroleum consumption by 20 percent by 2005 based on their FY1999 usage levels and states that "agencies shall use alternative fuels to meet a majority of the fuel requirements" of AFVs (White House, 2000). Figure 3 shows the number of AFVs owned by the federal government, the DoD, and the Air Force in relation to the total number of vehicles owned by each organization. The E.O. 13149 guidance document provides agencies with crucial information on E.O. 13149 reporting requirement and approaches that can be incorporated to reduce fuel consumption by 20 percent. The two

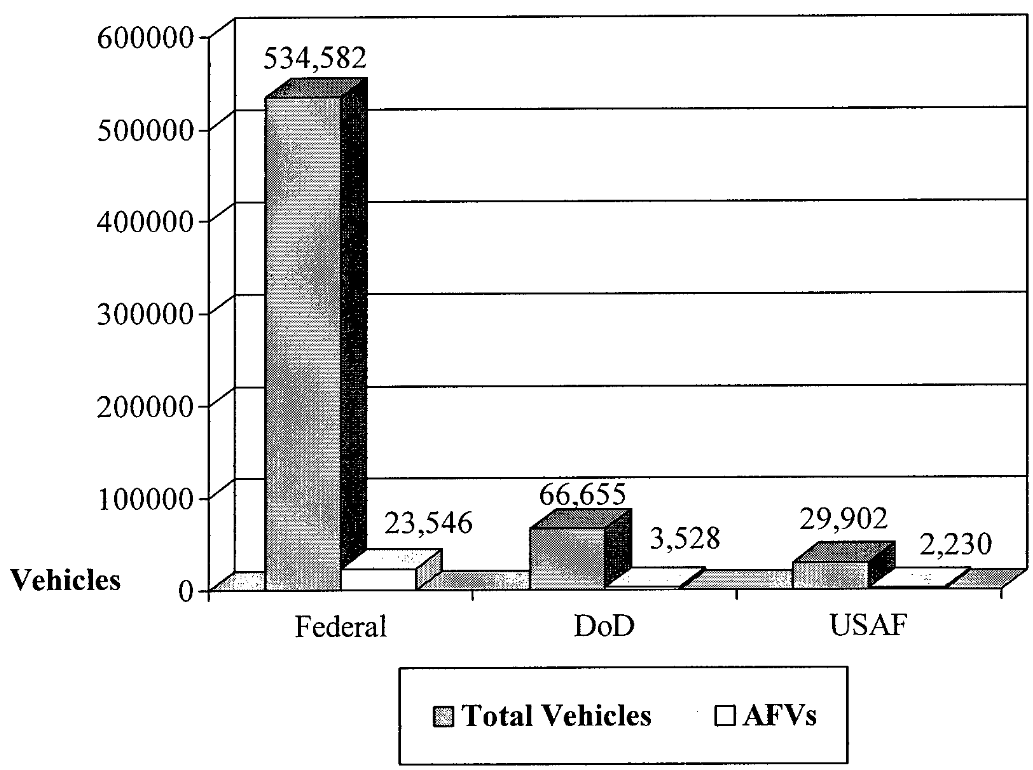

Figure 3. Comparison of AFVs Owned and Total Vehicles Owned
(FY1998 Federal Fleet Report, 2000)

primary approaches provided by the DOE for meeting E.O. 13149 requirements are listed below:

- Acquisition of alternative fuel vehicles and use of alternative fuels
- Acquisition of higher fuel economy vehicles (Department of Energy, 2000a).

> These two approaches shall be included in each agency's plan, unless an agency can demonstrate why these approaches are not feasible for its particular situation and present viable alternate approaches that will be implemented. (Air Force Alternative Fueled Vehicle System Program Office, 2001:1)

The E.O. 13149 guidance also provides three optional approaches that may facilitate a reduction in fuel consumption (Department of Energy, 2000a). Federal agencies may use all, part, or none of the three optional approaches based on what best suits their needs. The three optional approaches are listed below:

- The use of alternative fuels in medium- and heavy-duty vehicles
- An increase in vehicle load factors
- A decrease in vehicle miles traveled (VMT) (Department of Energy, 2000a).

Both the DoD and the federal government have acquired AFVs in an effort to meet EPACT 1992 acquisition requirements and both have opted to make CNG their alternative fuel of choice. Figure 4 shows the DoD's 1998 AFV fleet and Figure 5 shows the federal government's 1998 AFV fleet. Why has CNG gained such prominence in recent years? Officials at Hill Air Force Base Utah, state that CNG has been selected among other alternative fuels because of its:

- low cost
- market availability
- low emission generation rate when compared to conventional petroleum-based fuel and other petroleum fuel substitutes (Watkins, 2000).

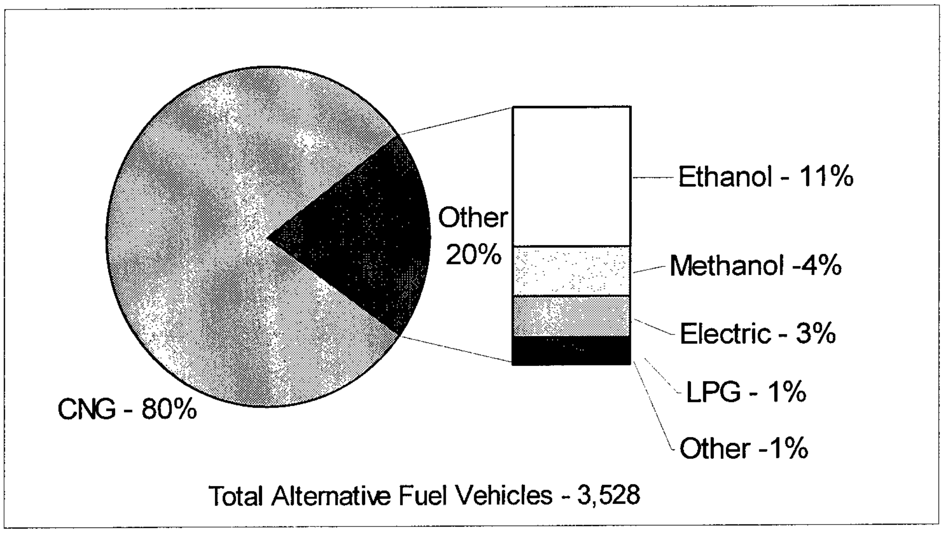

Figure 4. 1998 DoD Alternative Fuel Vehicle Fleet
(FY1998 Federal Fleet Report, 2000)

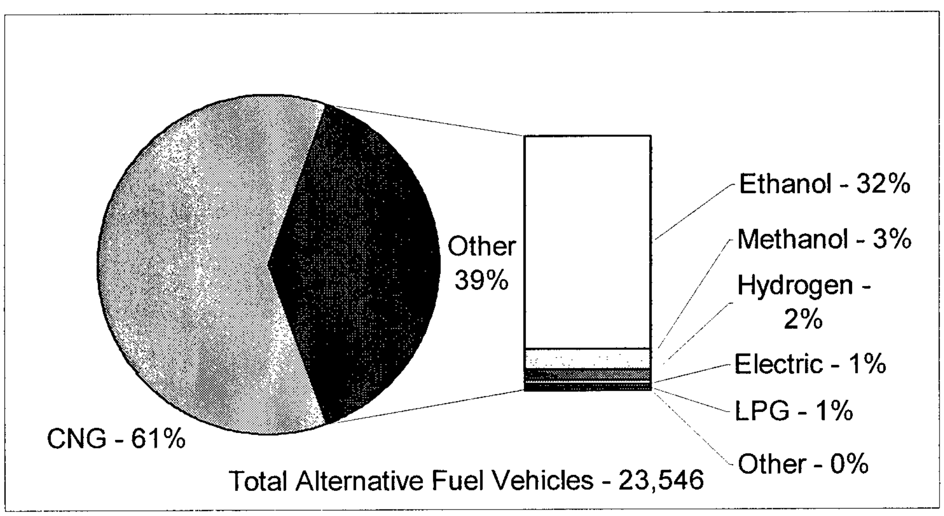

Figure 5. 1998 Federal Government Alternative Fuel Vehicle Fleet
(FY1998 Federal Fleet Report, 2000)

According to a paper prepared for the 1998 Transportation Research Board Summer Meeting, some drawbacks of using CNG include:

- higher first cost of NVGs (Natural Gas Vehicles)
- limited fueling infrastructure
- limited availability of Original Equipment Manufacturer (OEM) models
- concerns with operational characteristics of NVGs: e.g., range, efficiency, power, trunk space, weight, safety, maintenance, etc. (Anderson, 2000)

Some advantages and disadvantages of various alternative fuels and alternatively fueled vehicles will provide an understanding of some of the costs and requirements associated with the first approach, which is the "acquisition of alternative fuel vehicles and use of alternative fuels" (Department of Energy, 2000a).

Alternative Fuels and Alternatively Fueled Vehicles

An overview of four commonly available alternative fuels, CNG, methanol, propane (liquefied petroleum gas), and electricity in addition to a look at the advantages and disadvantages of each fuel and the AFVs associated with their use is provided. CNG is the first alternative fuel discussed.

CNG is a low emission fuel due to its composition, which includes very little nitrogen and sulfur. From a national security point of view, a higher percentage of fuel that originates from domestic sources is preferable. Domestic sources provide 90 percent of the CNG the nation consumes (Department of Energy, 2000d). According to the DOE,

there are approximately 75,000 CNG vehicles in the United States (Department of Energy, 2000d).

A major concern regarding the use of CNG is the number of refueling stations. There are approximately 1300 stations in the United States which are located in 46 states and the District of Columbia (Department of Energy, 2000d). In contrast, there are over 180,000 gasoline stations that operate throughout the United States. There are two types of fueling procedures for CNG, "slow fill", which can take up to eight hours and "fast fill", which takes between three and five minutes. The fueling process is similar to that of gasoline fueling. According to a report by the Pacific Northwest's Pollution Prevention Resources Center (PPRC), "The performance of NGVs (natural gas vehicles) is comparable to that of gasoline-powered vehicles. NGVs experience no loss of power, and may have greater power and efficiency (Pacific Northwest, 2000). According the Department of Energy's Alternative Fuel Database Center (AFDC), a CNG vehicle's "Power, acceleration, and cruise speed are comparable with those of an equivalent internal-combustion engine", although CNG vehicles do have a shorter vehicle range (Department of Energy, 2000d). 1999 CNG vehicles got an average of 120-180 miles per tank, which is significantly less than that of gasoline vehicles (Pacific Northwest, 2000). The potential exists to reduce emissions such as carbon monoxide (CO), non-methane organic gas, nitrogen oxide (NOx), and carbon dioxide (CO_2) with the use of natural gas. The PPRC report states that, on a emissions per vehicle mile traveled basis, "specific emission reductions for NGVs compared to gasoline vehicles are:

- CO, 65 – 90%
- Non-methane organic gas (NMOG), 87%

- NOx, 87%
- CO_2, by almost 20% (Pacific Northwest, 2000).

Vehicles must be designed or altered for the use of CNG, and according to figures provided by the Natural Gas Vehicle coalition, "The typical cost to convert a light duty gasoline vehicle to run on natural gas ranges from $3,000 to $5,000. Converting larger vehicles, such as trucks and school buses, costs more" (Department of Energy, 2000d). The conversion consists primarily of installing a conversion system and a fuel delivery system, which will allow for the vehicle to run on CNG. Because the Air Force has chosen CNG as its primary alternative fuel, the growth and success of the CNG industry is of concern. The prospects of the CNG industry appear promising. According to the Committee on Alternative Transportation Fuels, "CNG is enjoying limited but increasing success as an alternative fuel in niche light vehicle applications, and a number of manufacturers offer CNG-fueled vehicles in the United States" (Transportation Research Board, 2000:4). In fact, "Many in the industry believe that CNG has the best market positioning among the alternative fuels to become a long-term player in the transportation sector" (Anderson, 2000).

Methanol (M85) is a liquid fuel, which is 85 percent methanol and 15 percent gasoline, and can be used in vehicles that have been either designed or altered for M85 use (Air Force Center for Environmental Excellence, 2000a). Domestic sources provide 90 percent of the methanol the nation consumes (Department of Energy, 2000e). According to the DOE, there are approximately 20,000 methanol flexible fuel vehicles in the United States (Department of Energy, 2000e). There are only 41 methanol refueling

stations in the country, 35 of which are located in California. The methanol fueling process is the same as gasoline fueling. According to the AFDC, when comparing it to gasoline-powered vehicles, methanol-powered vehicles get less mileage per gallon (Department of Energy, 2000e). For example "A mid-size car with a 16-gallon tank can travel 424 highway miles on gasoline and 249-258 miles on methanol (based on 26.5 m.p.g. on gasoline)" (Pacific Northwest, 2000). According to the PPRC report "Emissions from M-85 vehicles are slightly lower than in gasoline powered vehicles". Smog-forming emissions are generally 30-50 percent lower" (Pacific Northwest, 2000). The report does however state that, "CO emissions are usually equal or slightly higher than in gasoline vehicles" (Pacific Northwest, 2000). Methanol may only be used in vehicles that are "specifically built to use methanol by the original equipment manufacturer" (American Methanol Institute, 2000). M85-compatible replacement parts and special M85 lubricants must be ordered directly from the supplier for oil changes, and come at a significant cost premium in comparison to conventional vehicle oil changes (Department of Energy, 2000e).

Liquefied petroleum gas (LPG) is a mixture of hydrocarbons such as propane, propylene, butane, and butylene, but because it is 90 percent propane it is also referred to as propane. Propane is a byproduct of "natural gas processing and petroleum refining" (Pacific Northwest, 2000). There are some similarities among CNG, methanol, and propane. Performance among the three is comparable to that of an "equivalent internal-combustion engine", but used in the same vehicle, their range on a full tank is lower than that of gasoline (Energy Source, 2000). As with CNG and methanol, propane's origins are almost entirely domestic. Domestic sources provide between 95 and 98 percent of the

propane that is consumed by the United States' 350,000 on- and off-road propane-burning vehicles (Energy Source, 2000). Propane burns cleaner than gasoline and in regard to tailpipe emissions such as carbon monoxide and nitrogen oxide, emissions of an LPG-powered vehicle are 40 percent that of a gasoline-powered vehicle (Department of Energy, 2000f). The cost of propane for vehicle use is, on average, less than that of gasoline. Propane is the most widely used alternative fuel in the United States, and there are over 10,000 fueling stations across the country (Energy Source, 2000). The propane fueling process is similar to filling a gas grill tank, and the time required is approximately the same as that of gasoline fueling. The conversion costs for a light-duty truck to use propane are approximately $2,500 regardless of whether it is factory-installed or done aftermarket (Energy Source, 2000). Regarding maintenance and reliability of vehicles using propane, although conventional maintenance is recommended, "some fleets report 2 to 3 years longer service life and extended time intervals between required maintenance" (Energy Source, 2000).

Electric vehicles are powered entirely by electricity stored in a battery. When the input energy is taken into account, over 95 percent of the electric-power is from domestic sources. There are more than 4,000 electric vehicles in use in the United States (Department of Energy, 2000g). Electric vehicles are often called zero-emission vehicles, but there are some alternative fuel authorities that disagree with that assertion. Both the AFDC and the PPRC agree that although electric vehicles produce no tailpipe emissions "there are emissions associated with the generation of electricity at the power plant" (Pacific Northwest, 2000 & Department of Energy, 2000g). The range of electric vehicles can vary greatly due to the numerous factors that can affect its battery. The

weight and number of batteries in addition to "the type of battery used, driving conditions, terrain, climate, and whether the driving is city or highway driving" all affect an electric vehicle's range (Pacific Northwest, 2000). As of 1999, some lead-acid batteries had a range of 72 miles whereas some nickel-metal-hydride batteries had a range of 96 to 126 miles (Pacific Northwest, 2000). The average range for electric vehicles offered by U.S. automakers is between 50 and 130 miles (Department of Energy, 2000h). There are 503 refueling stations across twenty states, and "public charging facilities are being developed in many areas…" (Department of Energy, 2000h). Comparing only the cost of fuel, electricity, on average costs less than gasoline on a mile-per-mile basis (Department of Energy, 2000h). The DOE also notes that upgrades in equipment or special hookups may be required (Department of Energy, 2000g). Another issue is the charging time, which can take from 4 to 8 hours, and is contingent upon such factors as temperature, size and type of battery, and the voltage of the electrical source being used for charging (Air Force Center for Environmental Excellence, 2000a). It should be noted however that "there are quick charge technologies that have been demonstrated to restore batteries to a 75% charge in 6 to 15 minutes" (Electric Vehicle Association of the Americas, 2001). Electric vehicles are the only AFVs that require battery replacement. The timing and cost of battery replacement will depend upon the type of battery used. Typically replacement is required between three and five years. The cost of replacement batteries can be a few thousand dollars for lead-acid batteries or as high as $15,000 for nickel-metal-hydride batteries (Pacific Northwest, 2000). Automakers include battery replacement as part of the electric vehicle lease agreement. Electric motors require significantly less maintenance than internal-combustion engine.

Electric vehicles eliminate the need for oil changes and tune ups, and equipment such as timing belts, water pumps, radiators and fuel injectors is no longer required (Department of Energy, 2000g). An overview of four alternative fuels: CNG, methanol, propane, and electricity was provided regarding the first DOE approach to meeting E.O. 13149, which is the "acquisition of alternative fuel vehicles and use of alternative fuels" (Department of Energy, 2000a). This discussion leads to the second required approach, which is to use more fuel-efficient vehicles.

Acquisition of Higher Fuel Economy Vehicles

Agencies can acquire high fuel economy vehicles such as hybrids that tend to be more fuel efficient than most conventional vehicles or can substitute current vehicles with more fuel efficient vehicles. This substitution may lead to agencies opting for the vehicle with the smallest engine that can meet operational needs. The use of hybrids is listed under this approach because the DOE does not count the "petroleum hybrids available today" as AFVs (Department of Energy, 2000a). A hybrid-electric vehicle (HEV) is:

> A vehicle powered by two or more energy sources, one of which is electricity. HEVs may combine the engine and fuel system of a conventional vehicle with the batteries and electric motor of an electric vehicle in a single drivetrain. (Department of Energy, 2001)

The use of alternative fuels, alternatively fueled vehicles, and vehicles with a higher fuel-efficiency are considered to be the primary approach in meeting E.O. 13149 requirements by the federal government. The DOE has listed three approaches for meeting E.O. 13149 as optional. The three optional approaches are: using alternative

fuels in medium- and heavy-duty vehicles, increasing vehicle load factors, and decreasing vehicle miles traveled.

The Use of Alternative Fuels in Medium- and Heavy-Duty Vehicles

The DOE has determined that the use of alternative fuels in medium- and heavy-duty vehicles, which weigh over 8,500 pounds, "can be a particularly successful approach for displacing significant amounts of petroleum because these vehicles typically use far more fuel per mile traveled than light-duty vehicles" (Department of Energy, 2000a). The use of alternative fuels in medium- and heavy-duty vehicles is listed as an option due to the fuel economies that can be gained. When compared with light-duty vehicles, these vehicles are considerably less fuel efficient. By "displacing significant amounts of petroleum", the use of alternative fuels in medium- and heavy-duty vehicles is viewed by the DOE as an effective approach in reducing petroleum consumption (Department of Energy, 2000a).

Increase Vehicle Load Factors

An agency can make maximum use of its vehicles by increasing its vehicle load factors. For example, if three employees go to a weekly meeting and usually two of the employees ride in a four-passenger sedan and the other rides in a two-passenger truck, then the sedan's vehicle load factors would be increased if all three employees rode in the sedan. This option entails using the vehicle size appropriate for the number of passengers that typically ride in it (Department of Energy, 2000a). Federal agencies can also reduce petroleum consumption by decreasing vehicle miles traveled.

Decrease Vehicles Miles Traveled

The most clear cut way to reduce fuel consumption is to simply drive less. Decreasing the number of vehicle miles traveled does not entail the AFV acquisition costs, the upfront costs of building alternative fuel infrastructure and developing an AFV program, and can be achieved when "traveling to nearby locations by combining the trips using one vehicle" (Department of Energy, 2000a). A drawback of carpooling is that "carpoolers must coordinate their travel times, which can be a major inconvenience" (Encyclopedia Britannica, 2001).

The five approaches listed in the DOE guidance document are wide-ranging and allow agencies some latitude in selecting the best way to meet the 20 percent reduction in fuel consumption. The two primary approaches, which include the acquisition of AFVs, the use of alternative fuels, and the acquisition of higher fuel economy vehicles, requires some planning on behalf of the federal agency. The Air Force must plan for vehicle acquisitions using its priority-buy (pri-buy) program.

Vehicle Pri-Buy Program

The Air Force compiles Major Command (MAJCOM) vehicle priority buy submissions and Program Objective Memorandum (POM) initiatives annually and submits them to the Office of the Secretary of Defense (OSD) and Congress (Department of the Air Force, 2001:Ch 2, 9). Air Force bases develop a Pri-Buy submission by prioritizing the vehicle types needed to meet mission requirements. The Pri-Buy submission must be completed in accordance with Warner-Robbins Air Logistic Center (WR-ALC) guidance. Each base then forwards its Pri-Buy submission to its MAJCOM.

Each MAJCOM consolidates the submissions and forwards them to WR-ALC (Department of the Air Force, 2001:Ch 2, 9). Vehicle requirements are first validated using the Air Force Equipment Management System. Vehicles are then purchased using vehicle replacement funds until they are exhausted (Department of the Air Force, 2001:Ch 2, 9). The quantities and types of vehicles on its Pri-Buy comprise part of the Air Force's Budget Estimate Submission (BES), which goes to the OSD for approval. Vehicles allocations are given to the MAJCOMS by WR-ALC. These allocations must then be approved by the OSD and Congress, and are tentative pending their decision (Department of the Air Force, 2001:Ch 2, 9). Figure 6 shows the Pri-Buy process, and the corresponding timeline.

Summary

This chapter presented background information necessary to analyze the Air Force's AFV policy and the use of CNG vehicles for meeting E.O. 13149 requirements. First, a brief description of EPACT 1992, as well as the rationale behind it was presented. A summary of the five compliance approaches was then provided. An overview of four common AFVs was presented. Finally, a review of the Air Force's vehicle Pri-Buy system was provided.

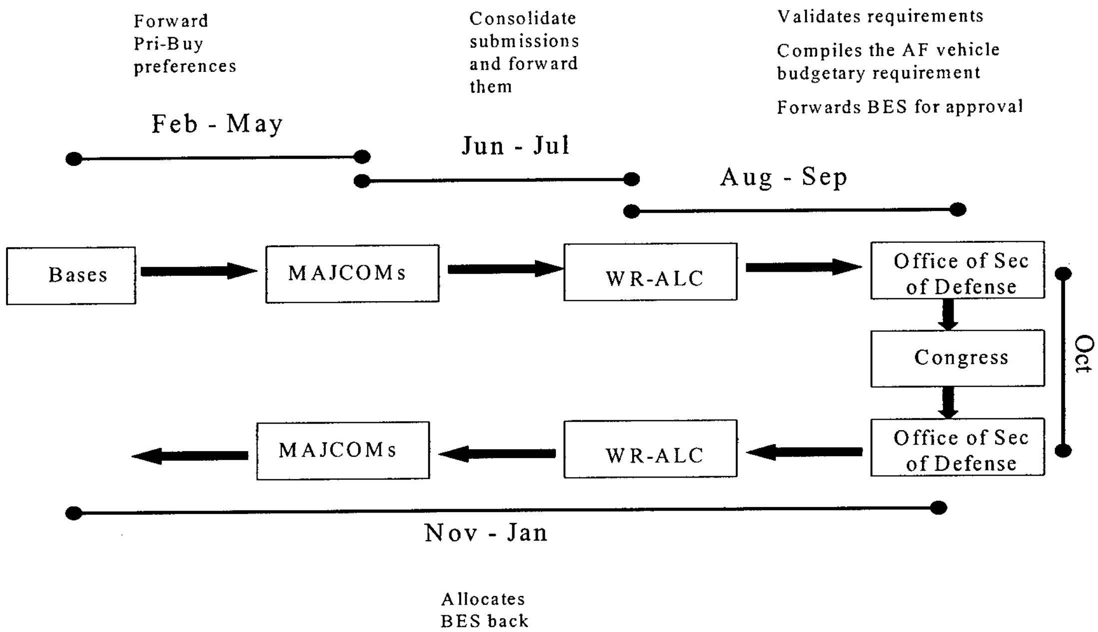

Figure 6. Pri-Buy Process and Timeline
(Warner Robins-Air Logistics Center, 2000)

III. Methodology

Introduction

This thesis will analyze the Air Force's AFV policy, which, in an effort to meet regulatory requirements, has focused heavily on the acquisition, conversion, and use of CNG vehicles. Various aspects of the Air Force's policy will be scrutinized in an effort to determine whether the AFV policy has been effective overall and to determine what the Air Force's best course of action should be to meet E.O. 13149 requirements. There are five areas of analysis. The analysis areas are:

- Analysis of E.O. 13149's Impact on Oil Dependence
- Analysis of the Advantages and Disadvantages of a CNG Vehicles as Compared to a Gas Vehicle
- Analysis of the Air Force's CNG Vehicle Fleet
- Analysis of the Air Force's AFV Policy and its Expected Results
- Analysis of the Air Force's CNG Vehicle Acquisition Policy

Analysis of E.O. 13149's Impact on Oil Dependence

By how much will the country's dependence on foreign oil be reduced if E.O. 13149 is complied with?

E.O. 13149 calls for a 20 percent reduction in petroleum fuel consumption by federal agencies with vehicle fleets. A primary objective of E.O. 13149 is to reduce the nation's dependence on foreign oil. Therefore, analysis will be accomplished to show the

impact that compliance with E.O. 13149 will have on the amount of foreign oil that is imported into the U.S. This analysis will be accomplished first at the Air Force level by comparing two pieces of data:

1. The number of gallons of petroleum that comprise the require 20 percent cut in the amount of petroleum consumed by the Air Force in 1998
2. The number of gallons of oil that were imported into the United States in 1998

This comparison will then be performed at the DoD level and the federal level by using DoD and federal 1998 petroleum fuel consumption data instead of Air Force data. Air Force, DoD, and federal petroleum usage data will be obtained from the FY1998 Federal Fleet Report. 1998 petroleum usage data will be used because 1999 petroleum usage data is not uniformly available for the three levels being analyzed. The imported petroleum data for 1998 will be obtained from the DOE.

Analysis of the Advantages and Disadvantages of a CNG Vehicle as Compared to a Gasoline Vehicle

What are the advantages and disadvantages of a CNG vehicle as compared to a gasoline vehicle for the Air Force?

Analysis will be accomplished to distinguish the advantages and disadvantages of CNG vehicles from those of gasoline vehicles. The following five characteristics will be compared:

1. Purchase price
2. Refueling infrastructure

3. Fuel price

4. Emissions

5. Maintenance costs

Data regarding the characteristics of both vehicle types will be garnered from various sources to include the Natural Gas Vehicle Coalition, the American Petroleum Institute, the DOE's AFDC, the AFVSPO, the Navy's Alternative Fuel Guide, and the EPA.

Analysis of the Air Force's CNG Vehicle Fleet

Is the Air Force's current dispersion of CNG vehicles and infrastructure effective?

An area of interest is the dispersion of CNG vehicles throughout the Air Force. The Air Force's AFV policy is geared towards meeting EPACT 1992 acquisition requirements, and this has translated to the establishment of AFV programs at Air Force units operating in MSAs. It is likely that the Air Force will continue to focus its AFV program on bases in or near MSAs because MSAs are covered by EPACT 1992. Analysis will be done to determine whether the Air Force has assigned CNG vehicles to units that can maximize the vehicles' effectiveness. Regarding Air Force units with CNG vehicles, effectiveness will be measured based upon two factors:

1. The unit's accessibility to CNG refueling infrastructure

2. The unit's location in relation to a Metropolitan Statistical Area (MSA)

Due to the fact that the size of Air Force installations where CNG vehicles are located varies greatly, from 600 acres to 463,000 acres, the average size of Air Force installations

with CNG vehicles was calculated. The average size of Air Force installations with CNG vehicles is approximately 43 square miles. This translates roughly to an area of 6.5 miles by 6.5 miles. For this analysis, a unit that is within 5 miles of a CNG refueling station will be considered to have access to CNG refueling infrastructure, and a unit will be considered to be in or near an MSA if the unit is within 75 miles of an MSA. The selection of a 75-mile radius was based on the guidance provided in Air Force Instruction (AFI) 24-301 titled Vehicle Operations, which states that the permissible operating distance of "75-mile radius is sufficient to support operations at most bases" (Department of the Air Force, 1998:Appendix 1). The analysis by comparison will be performed by:

1. Listing where the Air Force's CNG vehicles are assigned
2. Showing Air Force CNG Infrastructure locations
3. Listing bases that are in or near MSAs, which face stringent air pollution control requirements
4. Rating the effectiveness of CNG vehicle assignments by incorporating the unit's accessibility to CNG refueling infrastructure and the unit's location in relation to an MSA into a table. The effectiveness ratings will include highly effective, effective, or ineffective.

The Alternative Fueled Vehicle System Program Office (AFVSPO) at WR-ALC will supply data regarding the location of Air Force CNG vehicles along with a map of where the Air Force's CNG refueling stations are located. Data from the DOE's AFDC regarding the location of U.S. CNG refueling stations will also be used. The list of MSAs will be obtained from EPACT 1992.

Analysis of the Air Force's AFV Policy and its Expected Results

Will the Air Force's AFV policy produce expected results such as a reduction in emissions, an increase in alternative fuel consumption, and a reduction in petroleum fuel consumption?

There are four major vehicle emissions: non-methane hydrocarbons (NMHC), CO, NOx, and particulates, but for this analysis particulates are not being considered because the EPA has not calculated emission factors for the particulates of CNG combustion. The use of AFVs such as CNG vehicles instead of petroleum fueled vehicles has been shown to result in fewer emissions. A DOE comparison between a CNG vehicle and a vehicle using reformulated gasoline (RFG) of "ozone forming tailpipe emissions" showed that the "percentage of combined carbon monoxide and nitrogen oxide emissions" of the CNG vehicle were 20 percent of the RFG emissions (Department of Energy, 2000c). The EPA has defined RFG as "gasoline that is blended such that, on average, it significantly reduces Volatile Organic Compounds (VOC) and air toxics emissions relative to conventional gasolines" (Environmental Protection Agency, 2000). An analysis of the reduction in air emissions both projected and realized will be performed to determine whether projected reductions in emissions were actually realized. The analysis will consist of a comparison that looks at federal, DoD, and USAF fleets to determine by how much air emissions should have been reduced by the switch to CNG and by how much air emissions were actually reduced. The projected and realized amounts will be based on the number of CNG vehicles in the fleet and the portion of total vehicles in the fleet that they represent. Data for this analysis will be acquired from the

FY1998 Federal Fleet Report, the DOE's Alternative Fuels Data Center, and the EPA's AP-42, which is titled, Compilation of Air Pollutant Emission Factors.

In an effort to meet EPACT 1992 AFV acquisition requirements, the Air Force introduced CNG vehicles into its fleet in the mid-1990s. An analysis of the Air Force's CNG policy will be accomplished to determine whether usage has resulted in expected results such as a decrease in the amount of petroleum consumed and an increase in the amount of CNG consumed corresponding to the increased purchase of CNG vehicles. A comparison will be made to determine whether CNG consumption is proportionate to the number of CNG vehicles in the Air Force fleet. The data required to perform this analysis includes the amount of CNG consumed by the Air Force fleet in 1998 and 1999, the amount of petroleum consumed by the Air Force fleet in 1998 and 1999, and the number of CNG vehicles in the Air Force fleet. Petroleum consumption data will be obtained from the FY1998 Federal Fleet Report, CNG consumption data and CNG vehicle totals will be obtained from the FY1998 Federal Fleet Report and the AFVSPO at WR-ALC.

Analysis of the Air Force's CNG Vehicle Acquisition Policy

Has the Air Force optimized its use of funds with its previous CNG acquisition policy?

The Air Force's expenditure of funds regarding its CNG vehicle acquisition policy will also be analyzed. For this analysis, optimization will be defined as the maximum number of CNG vehicles that can be acquired per given amount of dollars. Due to the difference in cost of CNG Original Equipment Manufacture (OEM) installation versus the CNG after-market conversion cost, the Air Force expenditure on

AFVs is of particular interest. Analysis will be performed to determine if the Air Force expended funds to optimize the number of CNG vehicles in its fleet. The analysis will be accomplished via comparison. First, the difference between the number of CNG vehicles with OEM installed CNG equipment and the number of CNG vehicles with after-market installed CNG equipment will be compared. Second, the difference between the cost of CNG vehicles with OEM installed CNG equipment and the cost of CNG vehicles with after-market installed CNG equipment will be compared. The data required for this analysis includes:

1. The number of CNG vehicles in the Air Force fleet with OEM installed CNG equipment
2. The number of CNG vehicles in the Air Force fleet with after-market installed CNG equipment
3. The cost of OEM-installed CNG equipment
4. The cost of after-market installed CNG equipment

Cost estimates from the AFVSPO at WR-ALC and the Air Force Center for Environmental Excellence (AFCEE) will be obtained for the cost comparison analysis. The AFVSPO will also provide data regarding the number of CNG vehicles in the Air Force fleet that have OEM CNG equipment and the number of CNG vehicles in the Air Force fleet that have after-market CNG equipment.

Recommendations

The Air Force must often consider a number of factors when formulating a policy. Information from each of the five areas of analysis will be compiled to form a number of

recommendations regarding how the Air Force's AFV program can be modified to meet E.O. 13149 requirements. To determine how the Air Force's AFV program can be modified to meet E.O. 13149 requirements, a series of questions must be answered. First, does the Air Force intend to comply with E.O. 13149? If so, an assumption can then be made that the Air Force will follow DOE guidance and select the acquisition of AFVs and use of alternative fuels as one of its primary strategies in complying with E.O. 13149. The Air Force must then answer where should the AFVs be located? Finally, the Air Force must then decide how funds set aside for AFVs can be optimized? This thesis will address the aforementioned questions to provide a list of recommendations regarding how the Air Force's AFV program can be modified to meet E.O. 13149 requirements.

Summary

This chapter described the analysis that will be performed, and explained the manner in which it will be performed, in an effort to determine how the Air Force should modify its AFV program to meet the E.O. 13149 requirement to cut petroleum usage by 20 percent by 2005. The next chapter covers the analysis in detail.

IV. Results and Analysis

Analysis of E.O. 13149's Impact on Oil Dependence

A major stated objective of E.O. 13149 is to reduce our nations' dependence on imported oil. The rational for concentrating on reducing consumption was to address some deficiencies of EPACT 1992 that a February 2000 GAO report outlined. One such problem area is that:

> Aspects of the act's approach do not directly address its goals to replace petroleum fuels. For example, because the act mandated federal and state agencies and alternative fuel providers to meet certain acquisition targets for AFVs rather than establish targets for alternative fuel use, some AFVs acquired under the fleet mandate are being fueled with gasoline. (GAO, 2000:5)

The E.O. 13149's requirement to cut petroleum consumption and E.O. 13149's requirement that agencies "use alternative fuels to meet a majority of the fuel requirements of those motor vehicles by the end of FY2005" speaks to this problem area. Some strategies for meeting these requirements are directed at other problem areas noted in the report (GAO, 2000:2). According to the GAO, "The act also limits its focus to light-duty vehicles and does not include other ways to reduce petroleum consumption, such as increasing the use of alternative fuels in heavy-duty vehicles or mandating the use of vehicles that consume gasoline more efficiently" (GAO, 2000:5). E.O. 13149 directly addresses the aforementioned problem areas by including GAO suggestions as strategies for reducing petroleum consumption. The AFV acquisition requirements in EPACT 1992 were incorporated into E.O. 13149, in an effort to continue the federal government's leadership role in the acquisition and use of AFV. The federal government's ability to

provide leadership in this area does come at a price. According to the Congressional Budget Office's annual budget report to Congress, which provides options for reducing federal spending, "eliminating the EPACT requirement would save $107 million in federal transportation costs through 2010" (Congressional Budget Office, 2000). E.O. 13149 was issued only two months after the GAO report was released, and appears to fill in some of the gaps that were a result of EPACT 1992 acquisition requirements.

Oil import reduction is at the heart of E.O. 13149. Therefore, analysis was performed to demonstrate the impact that compliance with E.O. 13149 will have on the amount of foreign oil that is imported into the U.S. Due to the fact that E.O. 13149 addresses petroleum consumption, which is often measured in gallons, the figures for this analysis are shown in gallons. 1998 data was used because 1999 data for all the federal government, the DoD and the Air Force was unavailable. Two sets of data were used to perform this analysis. The first set is listed below:

- Average barrels of oil imported into the U.S. in 1998 - 9,763,530 barrels a day (Department of Energy, 2000i)
- Gallons of oil in a barrel – 42 gallons (American Petroleum Institute, 2001.)
- Gallons of oil required to produce a gallon of gasoline – approximately 2 gallons (American Petroleum Institute, 2001.)

The second set consists of petroleum consumption data for the Air Force, DoD, and federal government fleets. The amount of gallons of gasoline that the Air Force consumed in 1998 were then multiplied by .20 to calculate a 20 percent cut in petroleum consumption (see Equation 1).

$$\textit{20 percent cut} = \textit{7.2 million gallons} \times .20 = \textit{1.44 million gallons} \qquad (1)$$
$$\textit{gal} = \textit{gallons of gasoline}$$

The calculation in Equation 1 was then performed using DoD and federal government petroleum consumption data. The results are listed in Table 2. To calculate the impact that a 20 percent reduction in Air Force petroleum consumption will have on U.S. oil imports, two calculations were performed. First, to determine the gallons of gasoline from 1998 oil imports, the following calculation was performed (see Equation 2).

$$9{,}763{,}530 \text{ b/day} \times 42 \text{ gal/b} \times 1 \text{ gal of gas/2 gal of oil} \times 365 \text{ d/yr} \approx 75{,}000 \text{ million gal} \quad (2)$$

b/day = barrels of oil per day
gal/b = gallons of oil per barrel
gal of gas/2 gal of oil = 1 gallon of gasoline per 2 gallons of oil
d/yr = days per year
gal = gallons of gasoline

The following calculation, shown as Equation 3, compared the 20 percent reduction in Air Force petroleum consumption to the annual gallons of gasoline from imports.

$$1.4\text{m gal} \,/\, 75{,}000\text{m gal} = .0019\% \quad (3)$$

m gal = million gallons of gasoline

The calculation in Equation 2 was then performed using DoD and federal government petroleum consumption data. The results are listed in Table 2. Even if all agencies at the federal level cut petroleum consumption by 20 percent, the annual impact on oil imports would be much less than one percent. While E.O 13149 is aimed at decreasing the United States' dependence on oil imports, it appears that even with full compliance by all federal agencies it will only be minimally effective.

Table 2. Reduction as a Percentage of Annual Oil Imports

Organization	20% Cut of 1998 Gasoline Consumption	Gallons of Gasoline from Oil Imported in 1998	Reduction as Percentage of Annual Oil Imports
Air Force	1.4 million gallons	75 billion gallons	.0019%
DoD	7 million gallons	75 billion gallons	.0093%
Fed Govt	52 million gallons	75 billion gallons	.0693%

Analysis of the Advantages and Disadvantages of a CNG Vehicle as Compared to a Gasoline Vehicle

A comparison of CNG and gasoline shows a number of differences. While some of CNGs characteristics are viewed as advantages, others are distinct disadvantages. Analysis was accomplished to distinguish the advantages and disadvantages of CNG vehicles from those of gasoline vehicles. The following characteristics were compared:

1. Purchase price
2. Refueling infrastructure
3. Fuel price
4. Emissions
5. Maintenance costs

Purchase Price. Due to the various CNG and gasoline vehicle makes and models available, the difference in the purchase price when compared to gasoline vehicles varies. For bi-fuel vehicles, the DOE's Alternative Fuels Data Center states "the auto manufacturer's price premium can be $1500 to $6,000" (Department of Energy, 2000d). The average for this range is $3,750. Mr. Carl Perazzola from the AFVSPO has stated

that the premium for a bi-fuel CNG vehicle from the manufacturer averages about $6,500 (Perazzola, 2000). For this analysis, the two figures, $3,750 and $6,500, will be averaged to arrive at an estimated CNG premium of $5,000.

Due to the various makes and models that can be converted, conversion costs also vary. For bi-fuel vehicles, the DOE's Alternative Fuels Data Center states that an after-market "conversion costs about $2,000 to $3,000" (Department of Energy, 2000d). The average for this range is $2,500. An Air Force Center for Environmental Excellence (AFCEE) report also estimates the cost on a CNG conversion at $2,500. For this analysis, $2,500 will be used as the cost of a CNG conversion.

Refueling Infrastructure. There are approximately 180,000 gasoline stations and 1,300 CNG refueling stations (Department of Energy, 2000c.). The Air Force has gasoline stations at its installations so the acquisition cost of a gasoline station is not an issue, but the acquisition cost of a CNG fueling station is estimated to be approximately $175,000 (Air Force Center for Environmental Excellence, 2000b).

Fuel Price. The term gasoline gallon equivalent (gge) is used when comparing CNG to gasoline because CNG is a gas and gasoline is a liquid. A gge is the amount of fuel that has the "energy equivalent" or "range equivalent" of one gallon of gasoline (Department of the Navy, 2001:51). For bi-fuel vehicles, the DOE's Alternative Fuels Data Center states that for CNG, "fuel cost is less than that of gasoline, per gasoline gallon equivalent" (Department of Energy, 2000d). For this analysis, data from an April 2000 DOE Alternative Fuel Price Report , based on retail pump prices, will be used.

Nationwide, "gasoline averaged $1.52 per gallon" and "CNG average $.89 per gge" (Department of Energy, 2000j).

Emissions. The analysis involves a comparison of the emissions of vehicles using CNG and the emissions of vehicles using gasoline in grams per mile. The first piece of data required for the comparison is the emissions of a vehicle using CNG in grams per mile (g/mi) as calculated by the EPA in its study titled, Modeling Emission Factors for Compressed Natural Gas Vehicles (Environmental Protection Agency, 1999:2). The study used 2 light-duty vehicles (LDVs), 2 light-duty trucks class I (LDT1), and 2 light-duty trucks class II (LDT2) (Environmental Protection Agency, 1999:2). Neither a description of the vehicles' age nor the vehicles' make and model was provided in the study. 96 percent of the Air Force's 2000 CNG fleet is bi-fuel. It should be noted that the CNG emissions data is for dedicated CNG vehicles. This is noteworthy because there is currently some discussion on whether bi-fuel CNG vehicles may not burn as cleanly as dedicated CNG vehicles.

The second piece of data required for the comparison is the emissions of a vehicle using gasoline in grams per mile. Gasoline vehicle emissions were calculated using the EPA's Appendix H titled "Highway Mobile Source Emission Factors Table". The first step in the calculation process was the selection of the correct type of vehicle, for example LDV. The second step was to select the emission of interest. The third step was to set a year of usage, in this case 2000 was selected. The fourth step was to account for the age range of the Air Force fleet, which is zero to eight years old according to the Fleet Management office at Wright-Patterson Air Force Base (Stewart, 2001). This required

that each type of emission be averaged across years 1993 to 2000. The emissions were based on a low altitude area with a temperature of 75 degrees and vehicle speed of 19.6 miles per hour (Environmental Protection Agency, 2001a:Appendix H-41, Table 1.11A.1). A side-to-side comparison of the emissions for both fuels is shown in Table 3. For this analysis, the emissions listed in Table 3 will be used.

Table 3. Percent Change in Average Emissions from CNG and Gasoline Vehicles

Vehicle Type and Pollutant	Averag Emissions from CNGVs g/mi	Average Emissions from Gasoline Vehicles g/mi	Percent Change
LDV - NMHC	0.03	1.15	97% decrease
- CO	0.62	10.9	94% decrease
- NOx	0.06	0.79	92% decrease
LDT1 - NMHC	0.03	1.21	97% decrease
- CO	0.23	12.65	98% decrease
- NOx	0.12	0.94	87% decrease
LDT2 - NMHC	0.03	1.28	97% decrease
- CO	1.09	13.28	91% decrease
- NOx	0.47	1.13	58% decrease

The following abbreviations and definitions apply:

Hydrocarbons -NMHC– Hydrocarbon emissions result when fuel molecules in the engine do not burn or burn only partially. Hydrocarbons react in the presence of nitrogen oxides and sunlight to form ground-level ozone, a major component of smog.

Nitrogen Oxides – NOx – Under the high pressure and temperature conditions in an engine, nitrogen and oxygen atoms in the air react to form various nitrogen oxides, collectively known as NOx. Nitrogen oxides, like hydrocarbons, are precursors to the formation of ozone.

Carbon Monoxide – CO – Carbon monoxide is a product of incomplete combustion and occurs when carbon in the fuel is partially oxidized rather than fully oxidized to carbon dioxide.

LDV – Light-Duty Vehicle – a vehicle with a gross vehicle weight rating less than 8,500 pounds.

LDT1 – Light-Duty Truck 1 – a vehicle with a gross vehicle weight rating less than 6,000 pounds.

LDT2 – Light-Duty Truck 2 – a vehicle with a gross vehicle weight rating between 6,001 to 8,500 pounds.

CNVGs – Compressed Natural Gas Vehicles (Department of the Navy, 2001:51).

The emission data from Table 3 is graphically presented in Figure 7.

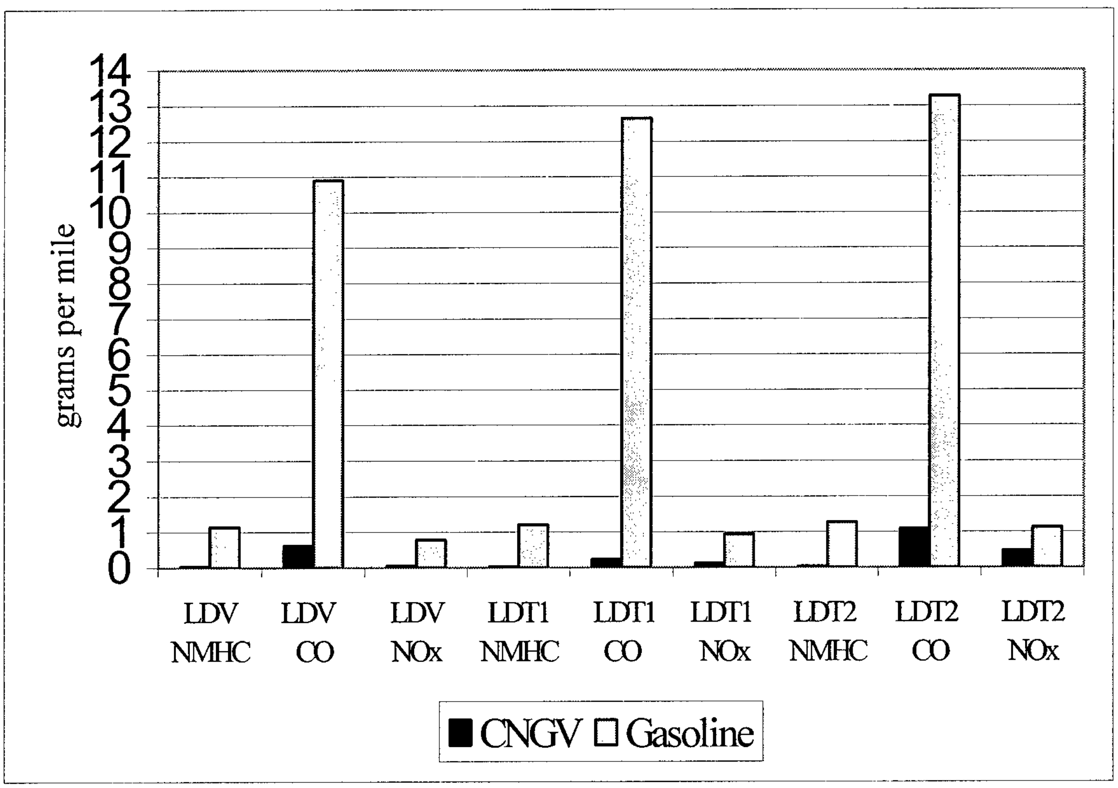

Figure 7. Difference in CNG and Gasoline Vehicle Emissions

Maintenance Costs. There is contradictory data regarding whether CNG vehicles require less maintenance than gasoline vehicles, thus resulting in lower maintenance costs. Regarding maintenance costs, the DOE has stated that, "some fleets report two to three years longer service life and extended time between required maintenance (Department of Energy, 2000d). According to a PPRC report "because CNG burns cleaner, there is a reduction in the vehicle maintenance needed" (Pacific Northwest, 2000). The DOE also stated that CNG "manufacturers and converters recommend conventional maintenance intervals" (Department of Energy, 2000d). In fact, a GAO report titled, Mass Transit Use of Alternative Fuels in Transit Buses, states that of eight transit operators surveyed "almost all of these operators reported higher maintenance costs for their compressed natural gas buses" (Scheinberg, 1999:2). Due to the fact that it is unclear whether CNG vehicles require less maintenance than gasoline vehicles, this characteristic will not be considered. Table 4 shows a comparison of CNG and gasoline characteristics. In the wake of decreasing federal budgets and slowing oil production, the Air Force has had to not just weigh purchase price and conversion costs, the number of refueling stations, fuel costs, and emissions, but also characteristics such as energy security and driving range.

Table 4. Comparison of Gasoline and CNG Characteristics

Criteria	Gasoline	CNG
Premium Cost of CNG vehicle as Compared to Purchase Price of Gas Vehicle	Standard	$5,000
CNG Conversion Cost	Standard	$2,500
Number of Fueling Stations	180,000	1300
Acquisition Cost for Fueling Station	$0*	Approximately $175,000
Fuels Costs per gasoline gallon equivalent (gge)	$1.52	$.89
CO Emissions **NOx Emissions** **NMHC Emissions**	Standard Standard Standard	Lower Lower Lower
Availability/Energy Security	Foreign dependency: 50% of oil consumed is imported	Foreign dependency: 10% of CNG consumed is imported
Driving Range with Equal Fuel Storage Volume	180 miles	36 miles
Spills/Leaks	A liquid that will pool on the ground	Is lighter-than air and will rapidly disperse.
Fuel Economy on a Volumetric Gallon Basis	Standard	75 – 85% loss
Trunk Space	Standard	Limited due to CNG tank
*Air Force has Pre-Existing Gasoline Refueling Infrastructure		

(AFVSPO, Navy AFV Guide & DOE webpage)

Analysis of the Air Force's CNG Vehicle Fleet

Analysis was performed to determine whether the Air Force has assigned CNG vehicles to units that can maximize the vehicles' effectiveness. Effectiveness was measured based upon two factors:

1. The unit's accessibility to CNG refueling infrastructure
2. The unit's location in relation to a Metropolitan Statistical Area (MSA)

Accessibility to CNG Refueling Infrastructure. Due to the limited number of CNG refueling stations, it is imperative that the Air Force locates its CNG vehicles near the necessary infrastructure if it is to maximize the vehicles' effectiveness. As of 2000, CNG vehicles were located at 74 Air Force units (Air Force Alternative Fueled Vehicle System Program Office, 2000). To determine whether the Air Force has assigned CNG vehicles to units that can maximize the vehicles' effectiveness, a comparison of the locations where Air Force CNG vehicles are assigned and the locations of existing CNG infrastructure was performed. The comparison was done in two phases. In the first phase, Air Force units with CNG vehicles, shown in Table 5, were matched up to existing Air Force CNG infrastructure, shown in Figure 8. If a match was made, then the unit was eliminated from further discussion. For example, Langley Air Force Base was one of the bases eliminated in the first phase because it has CNG vehicles and CNG infrastructure to support the vehicles. The 21 Air Force units, which did not match up with Air Force CNG infrastructure are listed in Table 6.

Table 5. Air Force Units with CNG Vehicles

Air Force Bases with CNG Vehicles	**Air Force Reserve Units, Air Natural Guard Units, and Direct Reporting Units with CNG Vehicles**
	Air Force Bases with Air National Guard or Air Force Reserve units collocated are listed as AFB/ANG or AFB/AFR
Andrews AFB MD	Andrews AFB/AFR MD
Barksdale AFB LA	Buckley Air National Guard Base CO
Bolling AFB D.C.	Cheyenne Municipal Airport WY
Charleston AFB SC	Dobbins AFB GA
Davis-Monthan AFB AZ	Fort Smith Regional Airport AR
Dover AFB DE	Fort Wayne International Airport IN
Edwards AFB CA	Fresno Air Terminal CA
Eglin AFB FL	Garden City GA
Elmendorf AK	General Mitchell Air Reserve Station WI
F.E. Warren AFB WY	Great Falls International Airport MT
Hanscom AFB MA	Grissom Air Reserve Base IN
Hill AFB UT	Kanawha County Airport/Yeager WV
Kelly AFB TX	Kellog Airport/Battle Creek MI
Kirtland AFB NM	Kelly AFB/ANG TX
Lackland AFB TX	Louisville KY
Langley AFB VA	Mansfield Municipal Airport OH
Luke AFB AZ	March Air Reserve Base CA
MacDill AFB FL	Martinsburg/Shepherd WV
Malmstrom AFB MT	McConnel AFB/ANG KS
Maxwell AFB AL	Naval Air StationJoint Reserve Base Fort Worth TX
McChord AFB WA	Naval Air StationJoint Reserve Base Willow Grove PA
McClellan AFB CA	New Boston Air Station NH
McGuire AFB NJ	Robins AFB/ANG GA
Nellis AFB NV	Savannah International Airport GA
Offut AFB NE	St. Paul International Airport MN
Patrick AFB FL	Tinker AFB/AFR OK
Peterson AFB CO	United States Air Force Academy
Randolph AFB TX	Volk Field WI
Robins AFB GA	Willow Grove Air Reserve Station PA
Shriever AFB CO	Will Rogers Air National Guard Base Ok
Scott AFB IL	Youngstown-Warren Regional Airport OH
Tinker AFB OK	440 Air Wing General Mitchell International Airport WI
Travis AFB CA	441 Air Wing General Mitchell International Airport WI
Tyndall AFB FL	442 Air Wing General Mitchell International Airport WI
Vance AFB OK	443 Air Wing General Mitchell International Airport WI
Vandenberg AFB CA	444 Air Wing General Mitchell International Airport WI
Wright-Patterson AFB OH	934 Air Wing Minneapolis-St. Paul MN

(Air Force Alternative Fueled Vehicle System Program Office, 2000)

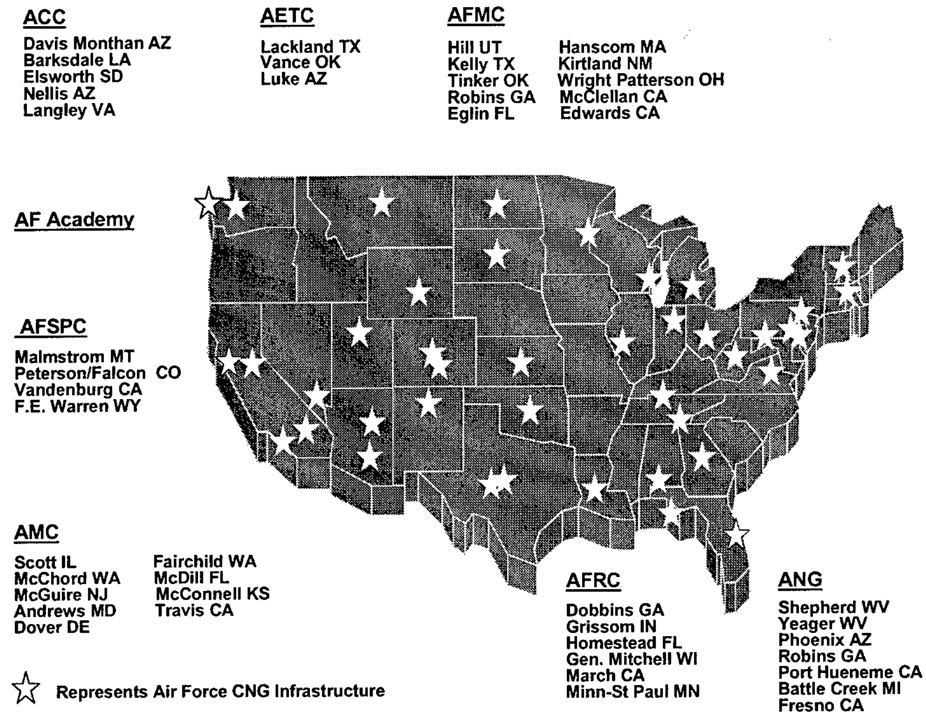

Figure 8. Air Force CNG Infrastructure
(Air Force Alternative Fueled Vehicle System Program Office, 2000)

Table 6. Air Force Units Not Matched to Air Force CNG Infrastructure

Air Force Bases with CNG Vehicles	**Air Force Reserve Units, Air Natural Guard Units, and Direct Reporting Units with CNG Vehicles**
	Air Force Bases with Air National Guard or Air Force Reserve units collocated are listed as AFB/ANG or AFB/AFR
Bolling AFB D.C.	Buckley Air National Guard Base CO
Charleston AFB SC	Fort Smith Regional Airport AR
Elmendorf AK	Fort Wayne International Airport IN
Maxwell AFB AL	Garden City GA
Offut AFB NE	Louisville KY
Patrick AFB FL	Mansfield Municipal Airport OH
Randolph AFB TX	Naval Air StationJoint Reserve Base Fort Worth TX
Tyndall AFB FL	Naval Air StationJoint Reserve Base Willow Grove PA
	New Boston Air Station NH
	Savannah International Airport GA
	Volk Field WI
	Willow Grove Air Reserve Station PA
	Youngstown-Warren Regional Airport OH

In the second phase, the remaining 21 Air Force units were matched up to existing non-Air Force owned CNG infrastructure. The DOE's alternative fuel refueling station locator was used to match the remaining Air Force units to non-Air Force owned CNG infrastructure. The locator, from the DOE's AFDC website, was accessible and user-friendly (Department of Energy, 2001).

To find a refueling station, the user first inputs a zip code, specifies a radius, and selects an alternative fuel. The locator then provides a map and the address of the CNG refueling station(s) that meet the parameters. If there are no refueling stations within the given radius, then the user can increase the radius until a station is located.

To determine whether the remaining units with CNG vehicles were located within five miles or less of CNG infrastructure, the units' zip codes were taken from the Air Force Officer's Handbook for use with the refueling station locator. Each unit's zip code was input into the locator. If a match was made, then the unit was eliminated from further discussion. Table 7 shows that 13 of the 21 remaining units are located more than 5 miles from CNG fueling infrastructure. As Table 7 illustrates, 149 CNG vehicles are located at units which are more than 5 miles from CNG infrastructure. As Figure 9 shows, only six percent of the Air Force's CNG fleet is located at Air Force units that are more than 5 miles from existing CNG infrastructure (Air Force Alternative Fueled Vehicle System Program Office, 2000a). Table 7 shows that only one dedicated CNG vehicle, which is at Patrick AFB, Florida is located more than 5 miles from CNG infrastructure. Another issue that was considered and is related to the effective management of CNG vehicles is whether the Air Force has located them in or near MSAs in an effort to meet EPACT 1992 requirements.

Table 7. Units with CNG infrastructure farther than 5miles away

Air Force Bases with CNG Vehicles	CNG OEM	CNG Conv	CNG Ded	CNG Total
Air Force Bases with Air National Guard or Air Force Reserve units collocated are listed as AFB/ANG or AFB/AFR				
Charleston AFB SC	2			2
Elmendorf AK	3			3
Fort Wayne International Airport IN	5			5
Mansfield Municipal Airport OH	4			4
Maxwell AFB AL	10			10
Naval Air Station JRB Fort Worth TX	4			4
New Boston Air Station NH	2			2
Offut AFB NE		32		32
Patrick AFB FL	5	5	1	11
Randolph AFB TX	17	36		53
Tyndall AFB FL	1	9		10
Volk Field WI	2			2
Youngstown-Warren Regional Airport OH	0	11	0	11
Totals	55	93	1	149
CNG OEM = Vehicle with CNG equipment from the Original Equipment Manufacture				
CNG Conv = Vehicle with CNG equipment due to an after-market conversion				
CNG Ded = Vehicle with dedicated CNG equipment				
JRB = Joint Reserve Base				

<u>The Units' Location in Relation to an MSA</u>. The analysis to determine whether the Air Force has located CNG vehicles at units within 75 miles of an MSA was performed. The list of Air Force units with CNG vehicles was compared to the EPACT 1992 list of

MSAs (Office of Governmentwide policy, 2000). Each unit on the list was first found in the Officer's handbook to ascertain its geographical location.

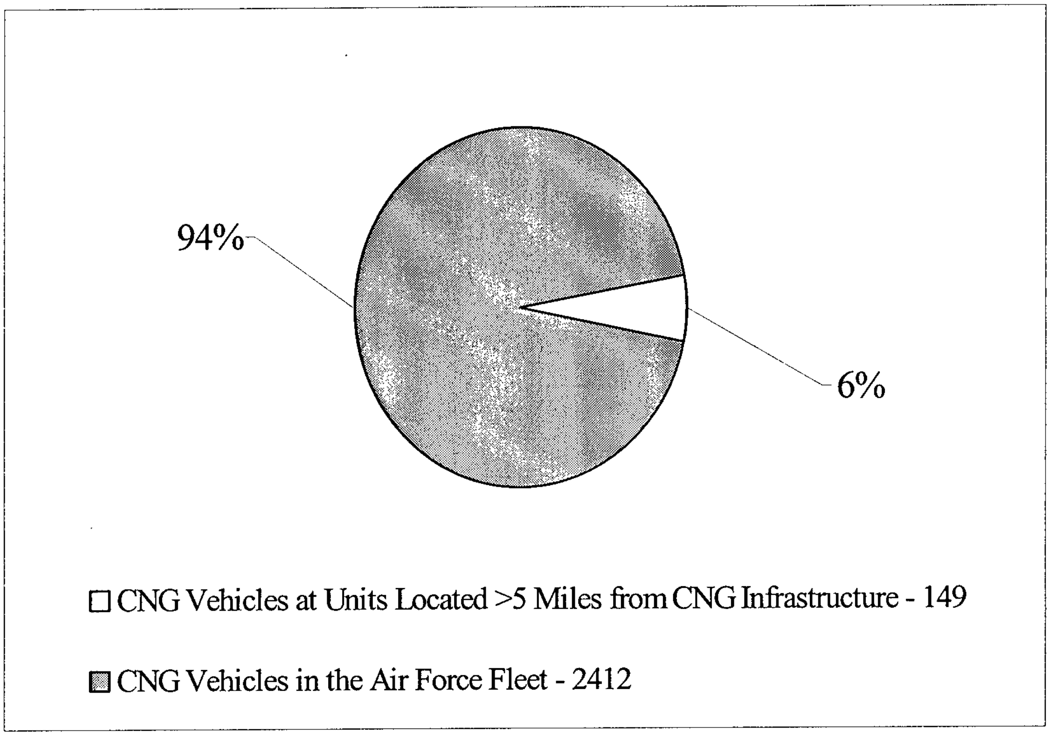

Figure 9. Air Force Units with CNG Infrastructure More Than 5 Miles Away

The location of the unit was then found in the atlas and the unit's location was matched up against the list of MSAs, which is found in Table 8 (Road Atlas, 1999). As Table 9 shows, 60 of the 74 Air Force units with CNG vehicles are located within 75 miles of an MSA. It appears the Air Force has located the majority of its CNG vehicles in or near an MSA. This is of interest because the Air Force must meet EPACT 1992 acquisition requirements, and MSAs are the locations subject to EPACT 1992 requirements.

Table 8. List of the 125 MSAs under Energy Policy Act of 1992

Metropolitan Statistical Areas (MSAs) Covered by EPACT 1992		
Albany-Schenectady-Troy, NY	Albuquerque, NM	Allentown-Bethlehem PA-NJ
Appleton-Oshkosh-Neenah, WI	Atlanta, GA	Atlantic City, NJ
Augusta, GA-SC	Austin, TX	Bakersfield, CA
Baltimore, MD	Baton Rouge, LA	Beaumont-Port Arthur, TX
Binghamton, NY	Birmingham, AL	Boston-Lawrence-Salem, MA-NH
Buffalo-Niagara Falls, NY	Canton, OH	Charleston, SC
Charleston, WV	Charlotte-Gastonia-Rock Hill, NC-SC	Chattanooga TN-GA
Chicago-Gary-Lake County, IL-IN-WI	Cincinnati-Hamilton, OH-KY-IN	Cleveland-Akron-Lorain, OH
Colorado Springs, CO	Columbia, SC	Columbus, OH
Corpus Christi, TX	Dallas-Ft Worth, TX	Davenport-Rock Island-Moline, IA-IL
Dayton-Springfield, OH	Daytona Beach, FL	Denver-Boulder, CO
Des Moines, IA	Detroit-Ann Arbor, MI	Duluth, MN
El Paso, TX	Erie, PA	Eugene-Springfield, OR
Evansville, IN-KY	Flint, MI	Ft Wayne, IN
Fresno, CA	Grand Rapids, MI	Greensboro-Winston-Salem-High Point, NC
Greenville-Spartanburg, SC	Harrisburg-Lebanon-Carlisle, PA	Hartford-New Britain-Middletown, CT
Honolulu, HI	Houston-Galvaston-Brazoria, TX	Huntington-Ashland, WV-KY-OH
Indianapolis, IN	Jackson, MS	Jacksonville, FL
Johnson City-Kingsport-Bristol, TN-VA	Johnstown, PA	Kansas City, MO-KS
Knoxville, TN	Lakeland-Winter Haven, FL	Lancaster, PA
Lansing-East Lansing, MI	Las Vegas, NV	Lexington-Fayette, KY
Little Rock-N. Little Rock, AR	Los Angeles-Anaheim-Riverside, CA	Louisville, KY-IN
Macon-Warner Robins, GA	Madison, WI	McAllen-Edinburg-Mission, TX
Melbourne-Titusville-Palm Bay, FL	Memphis, TN-AR-MS	Miami-Ft Lauderdale, FL
Milwaukee-Racine, WI	Minneapolis-St Paul, MN-WI	Mobile, AL
Modesto, CA	Montgomery, AL	Nashville, TN
New Haven-Meriden, CT	New London-Norwich, CT-RI	New Orleans, LA
New York-Northern NJ-Long Island, NY-NJ-CT	Norfolk-Virginia Beach- Newport News, VA	Oklahoma City, OK
Omaha, NE-IA	Orlando, FL	Pensacola, FL
Peoria, IL	Philadelphia- Wilmington- Trenton, PA-NJ-DE, MD	Phoenix, AZ
Pittsburgh-Beaver Valley, PA	Portland-Vancouver, OR-WA	Providence-Pawtucket-Fall River, RI-MA
Raleigh-Durham, NC	Reading, PA	Richmond-Petersburg, VA
Rochester, NY	Rockford, IL	Sacramento, CA
Saginaw-Bay City-Midland, MI	St Louis, MO-IL	Salinas-Seaside-Monterrey, CA
Salt Lake City-Ogden, UT	San Antonio, TX	San Diego, CA
San Francisco-Oakland-San Jose, CA	Santa Barbara-Santa Maria-Lompoc, CA	Scranton-Wilkes-Barre, PA
Seattle-Tacoma, WA	Shreveport, LA	Spokane, WA
Springfield, MA	Stockton, CA	Syracuse, NY
Tampa-St Petersburg-Clearwater, FL	Toledo, OH	Tucson, AZ
Tulsa, OK	Utica-Rome, NY	Washington DC-MD-VA
West Palm Beach-Boca Raton-Delray Beach, FL	Wichita, KS	Worchester, MA
York, PA	Youngstown-Warren, OH	

<u>Rating the Effectiveness of the Air Force's CNG Vehicle Assignments</u>. To determine whether the Air Force has assigned CNG vehicles to units that can maximize the vehicles' effectiveness, the Air Force's assignments of CNG vehicles were rated. The three effectiveness ratings are:

- Highly effective – this rating is assigned if a unit is within 5 miles of CNG infrastructure and is within 75 miles of an MSA
- Effective – this rating is assigned if a unit is within 5 miles of CNG infrastructure, but not within 5 miles of CNG infrastructure
- Ineffective – this rating is assigned if a unit is neither within 5 miles of CNG infrastructure nor is within 75 miles of an MSA

The Air Force units with CNG vehicles and the effectiveness ratings the units received are listed in Table 9. The rating results show that the Air Force's assignment of CNG vehicles to 52 of the 74 units was highly effective. Nine of the 74 units were rated as effective, and the remaining 13 units were rated as ineffective. The results are illustrated in Figure 10. The Air Force's assignment of CNG vehicles to 61 of 74 units was determined to be either effective or highly effective. It appears that the majority of the Air Force Force's current dispersion of CNG vehicles and infrastructure is effective.

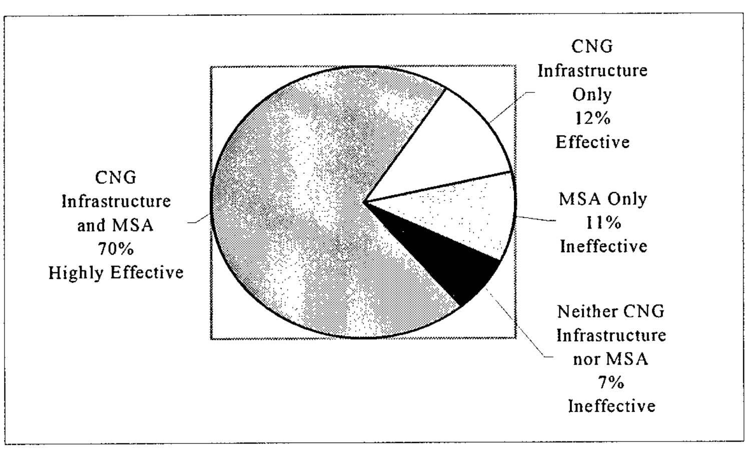

Figure 10. Effectiveness of CNG Vehicle Assignments

Table 9. Effectiveness Ratings of Air Force Units with CNG Vehicles

Unit with CNG Vehicle	**Unit within 5 miles of CNG Infrastructure**	**Unit Within 75 miles of an MSA**	**Effectiveness Rating**
Andrews AFB MD	X	X	Highly Effective
Andrews AFB/AFR MD	X	X	Highly Effective
Barksdale AFB LA	X	X	Highly Effective
Bolling AFB D.C.	X	X	Highly Effective
Buckley ANGB CO	X	X	Highly Effective
Davis-Monthan AFB AZ	X	X	Highly Effective
Dobbins AFB GA	X	X	Highly Effective
Dover AFB DE	X	X	Highly Effective
Edwards AFB CA	X	X	Highly Effective
Fresno Air Terminal CA	X	X	Highly Effective
General Mitchell ARS WI	X	X	Highly Effective
Grissom ARB IN	X	X	Highly Effective
Hanscom AFB MA	X	X	Highly Effective
Hill AFB UT	X	X	Highly Effective
Kanawha County Airport/Yeager WV	X	X	Highly Effective
Kellog Airport/Battle Creek MI	X	X	Highly Effective
Kelly AFB TX	X	X	Highly Effective
Kelly AFB/ANG TX	X	X	Highly Effective
Kirtland AFB NM	X	X	Highly Effective
Lackland AFB TX	X	X	Highly Effective
Langley AFB VA	X	X	Highly Effective
Louisville KY	X	X	Highly Effective
Luke AFB AZ	X	X	Highly Effective
MacDill AFB FL	X	X	Highly Effective
March ARB CA	X	X	Highly Effective
McChord AFB WA	X	X	Highly Effective
McClellan AFB CA	X	X	Highly Effective
McConnel AFB/ANG KS	X	X	Highly Effective
McGuire AFB NJ	X	X	Highly Effective
NASJRB Willow Grove PA	X	X	Highly Effective
Nellis AFB NV	X	X	Highly Effective
Peterson AFB CO	X	X	Highly Effective
Robins AFB GA	X	X	Highly Effective
Robins AFB/ANG GA	X	X	Highly Effective
Scott AFB IL	X	X	Highly Effective
Shriever AFB CO	X	X	Highly Effective
St. Paul IAP MN	X	X	Highly Effective
Tinker AFB OK	X	X	Highly Effective
Tinker AFB/AFR OK	X	X	Highly Effective
Travis AFB CA	X	X	Highly Effective
United States Air Force Academy	X	X	Highly Effective
Vance AFB OK	X	X	Highly Effective
Vandenberg AFB CA	X	X	Highly Effective
Will Rogers AGNB OK	X	X	Highly Effective
Willow Grove ARS PA	X	X	Highly Effective
Wright-Patterson AFB OH	X	X	Highly Effective
440 Air Wing Gen Mitchell IAP WI	X	X	Highly Effective
441 Air Wing Gen Mitchell IAP WI	X	X	Highly Effective
442 Air Wing Gen Mitchell IAP WI	X	X	Highly Effective
443 Air Wing Gen Mitchell IAP WI	X	X	Highly Effective
444 Air Wing Gen Mitchell IAP WI	X	X	Highly Effective
934 Air Wing Minneapolis-St. Paul MN	X	X	Highly Effective

Unit with CNG Vehicle	Unit within 5 miles of CNG Infrastructure	Unit Within 75 miles of an MSA	Effectiveness Rating
Cheyenne MAP WY	X		Effective
Eglin AFB FL	X		Effective
F.E. Warren AFB WY	X		Effective
Fort Smith RA AR	X		Effective
Garden City GA	X		Effective
Great Falls IAP MT	X		Effective
Malmstrom AFB MT	X		Effective
Martinsburg/Shepherd WV	X		Effective
Savannah IAP GA	X		Effective
Charleston AFB SC		X	Ineffective
Fort Wayne IAP IN		X	Ineffective
NASJRB Fort Worth TX		X	Ineffective
New Boston AS NH		X	Ineffective
Offut AFB NE		X	Ineffective
Patrick AFB FL		X	Ineffective
Randolph AFB TX		X	Ineffective
Youngstown-Warren RA OH		X	Ineffective
Elmendorf AK			Ineffective
Mansfield MAP OH			Ineffective
Maxwell AFB AL			Ineffective
Tyndall AFB FL			Ineffective
Volk Field WI			Ineffective

Analysis of the Air Force's AFV Policy and its Expected Results

A significant reduction in emissions, as stated earlier, is a major reason for the Air Force's selection of CNG as its alternative fuel of choice. Analysis was performed to determine the extent of reductions in emissions that could be achieved with the use of CNG vehicles. Data taken from the FY1998 Federal Fleet Report shows that Air Force gasoline vehicles were driven an average of 5,910 miles in 1998 (Office of Governmentwide Policy, 2000:27-45). As of 2000, the Air Force had 2,412 CNG vehicles. To determine the extent that the Air Force has reduced emissions with the use of CNG vehicles, actual CNG consumption data was taken into account for the analysis. Analysis was performed using Davis-Monthan Air Force Base's CNG consumption data. Four additional pieces of data were also used in the analysis: the average miles per gallon for a gasoline vehicle, average miles per gge for a bi-fuel CNG vehicle, gasoline vehicle

emissions in grams per mile for each of the three emissions, and the emissions for a CNG LDV in grams per mile for each of the three emissions. The average miles per gallon and average miles per gge data used for this analysis was obtained from the EPA's 2000 Fuel Economy Guide, and is reproduced in Table 10 (Environmental Protection Agency, 2001). To calculate the actual CNG vehicle emissions at Davis-Monthan Air Force Base,

Table 10. 2000 Chevrolet Cavalier Fuel Economy

Chevrolet	**Transmission**	**Engine**	**Cylinder**	**Avg miles/gal or miles/gge**	**Fuel**	**Range (miles)**
Cavalier (bi-fuel)	Auto	3.2	4	24	CNG	130
Cavalier (bi-fuel)	Auto	3.2	4	25	Gasoline	360

(Environmental Protection Agency, 2001b)

the number of gges the base consumed was multiplied by the average number of miles per gge then multiplied by the grams of emissions per mile of for each of the three types of emissions. The results are shown in Table 11. Equation 4 shows this calculation using NMHC emission data for Davis-Monthan Air Force Base.

$$\textit{319 gges x 24 mi/gge x .025 g/mi = 191 grams} \quad (4)$$
$$\textit{gges = gasoline-gallon equivalents}$$
$$\textit{mi/gge = miles per gasoline-gallon equivalent}$$
$$\textit{g/mi = grams per miles}$$

To calculate the gasoline vehicles emissions for equivalent fuel usage, the number of gges consumed by the base was converted to gallons of gasoline and was multiplied by the average number of miles per gallon then multiplied by the grams of emissions per

mile for each of the three types of emissions. Equation 5 shows this calculation using NMHC emission data for Davis-Monthan Air Force Base.

$$319 \text{ gal} \times 25 \text{ mi/gal} \times 1.15 \text{ g/mi} = 9171 \text{ grams} \tag{5}$$

gal = gallon of gasoline
mi/gal = miles per gallon of gasoline
g/mi = grams per miles

This analysis shows that even with its limited use of CNG vehicles, Davis-Monthan Air Force Base was able to reduce emissions by 8,980 grams. This figure was calculated by subtracting 191 grams from 9171 grams, to arrive at a 98% reduction (see Table 11).

Table 11. Comparison of Emissions at Davis-Monthan Air Force Base

Base	**CNG Vehicles Assigned**	**GGEs of CNG Consumed**	**Actual CNG Emissions grams/miles**	**Emissions of Equivalent Gasoline Usage grams/mile**	**% difference**
DMAFB	30	319	NMHC - 191 CO – 4,747 NOx - 444	NMHC – 9171 CO – 86,928 NOx – 6,284	98% 95% 93%
GGE – Gasoline Gallon Equivalent % difference - % difference between Actual and Possible DMAFB – Davis-Monthan Air Force Base WPAFB – Wright-Patterson Air Force Base					

Over the past few years, the Air Force has increased its number of CNG vehicles. An increase in the number of vehicles would suggest an increase in the amount of CNG consumed. This is, in addition to an expected increase in usage, as users become more familiar with the benefits of the CNG program. Analysis was performed regarding the change in Air Force AFV alternative fuel consumption from years 1999 to 2000. Figure 11 shows the change in CNG consumption from 1999 to 2000 for six Air Force

organizations. A comparison shows that while the number of CNG vehicles in the Air Force fleet increased by 275, reported alternative fuel consumption decreased by 15,984 gges from years 1999 to 2000, which is a 6 percent decrease (see Figure 11) (Air Force Alternative Fueled Vehicle System Program Office, 2000b). Because detailed 1999 information was not available for the Air Force Reserve and the Air National Guard, the comparisons made in Figure 11 did not include those organizations. Analysis to discern

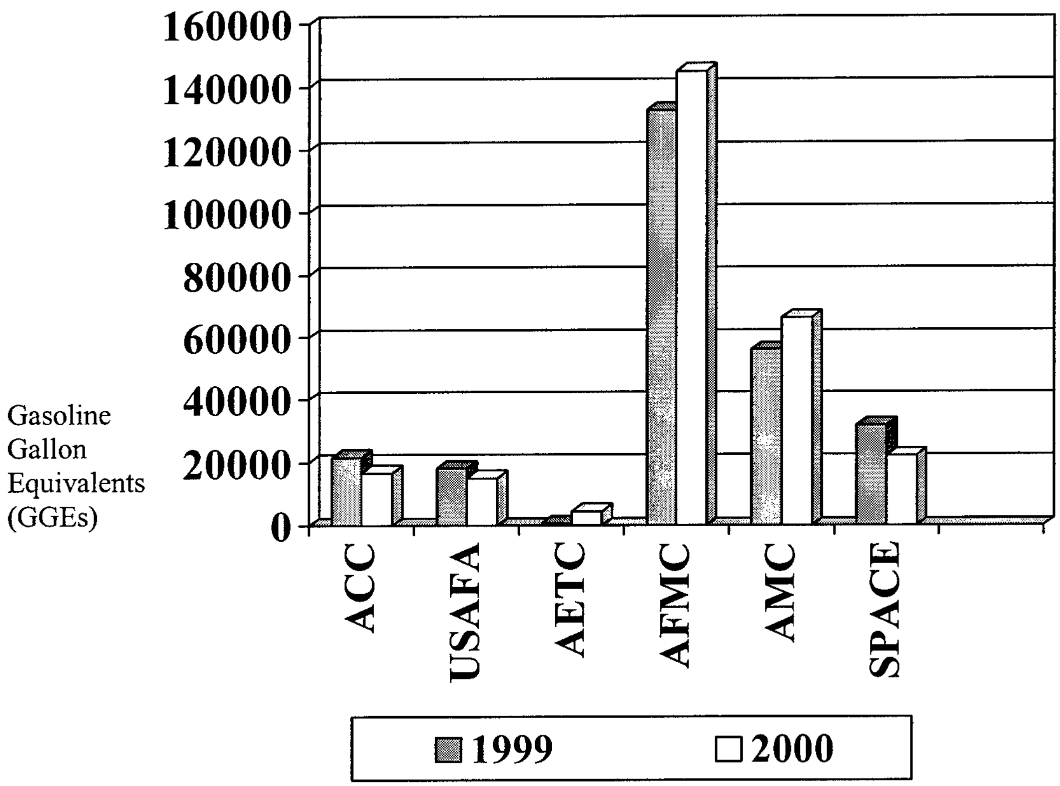

Figure 11. Difference in Alternative Fuel Consumed from 1999 to 2000

the average number of miles driven by CNG vehicles at Air Force units was performed by using the number of CNG vehicles assigned and their CNG consumption. The 1998

average number of gallons of petroleum consumed per Air Force vehicle, 241 gallons, was calculated using data in the 1998 Federal Fleet Report. This figure was calculated by dividing the amount of petroleum fuel the Air Force consumed in 1998, 7,217,869 gallons, by the number of vehicles in the Air Force fleet, 29,902 vehicles. As Figure 12 shows, ten units with CNG vehicles reported zero gges of CNG consumed. One such unit, Barksdale Air Force Base (AFB) has 65 CNG vehicles assigned in 1999, but reported zero CNG consumption. Analysis was performed to determine the impact that CNG usage could have on the amount of petroleum consumed by Barksdale Air Force Base. According to Fuels personnel at Barksdale AFB, in 1999 petroleum fuel usage by their vehicle fleet was 30,000 gallons. The 1998 average number of gallons of gasoline consumed per Air Force gasoline vehicle at Barksdale AFB was multiplied by the number of CNG vehicles assigned to Barksdale AFB (see Equation 6). This number was then compared to Barksdale's 1998 petroleum fuel usage (see Equation 7).

$$(241 \text{ gal} \times 65 \text{ vehicles}) = \text{possible reduction of } 15{,}665 \text{ gal} \qquad (6)$$
$$\text{gal} = \text{gallons of gasoline}$$

$$15{,}665 \text{ gal}/30{,}000 \text{ gal} = \text{a possible 52 percent reduction of petroleum use} \qquad (7)$$
$$\text{gal} = \text{gallons of gasoline}$$

It is important to note that General Services Administration (GSA) vehicles that the Air Force leases are not being considered in this thesis. The Air Force's AFV program does not appear to show an increase in the use of CNG in relation to the increase in the number of CNG vehicles.

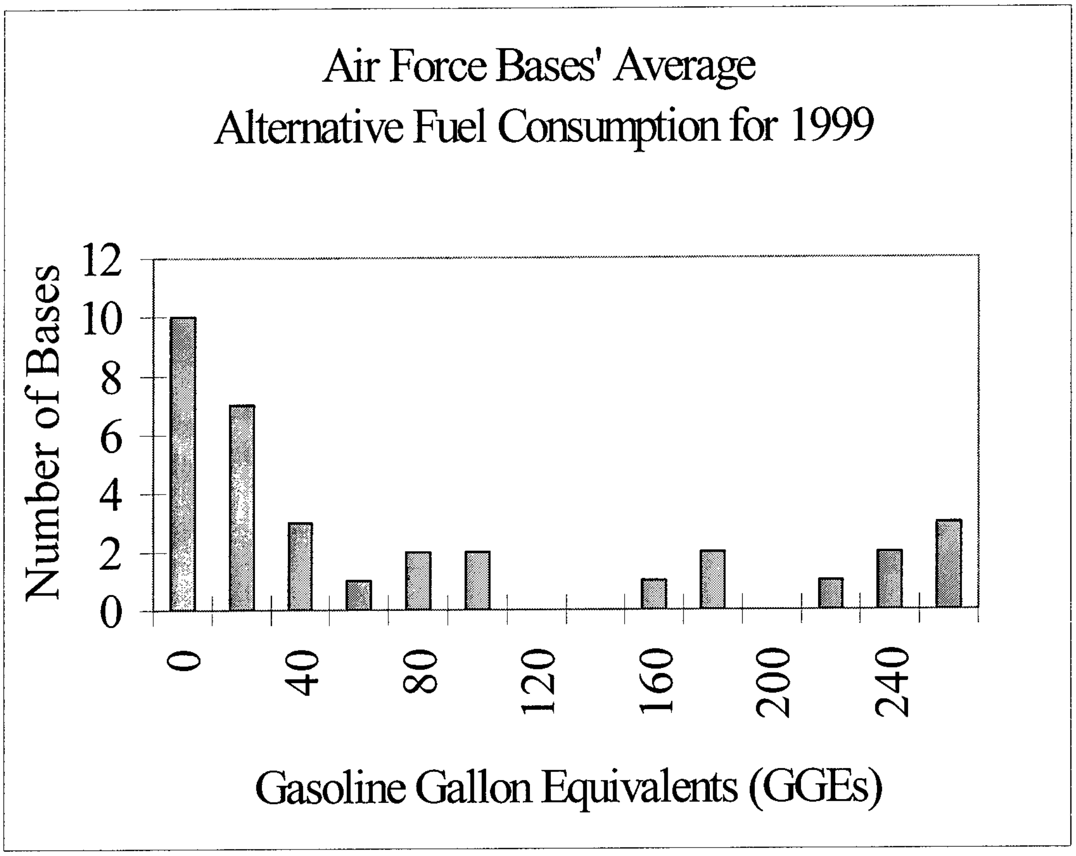

Figure 12. Air Force Bases' Average Alternative Fuel Consumption for 1999

Analysis was performed to determine the amount of gasoline that could be cut the Air Force by driving CNG vehicles at the same average rate as conventional vehicles. First, the 1998 average number of gallons of petroleum consumed per Air Force vehicle, 241 gallons (see Equation 8), was multiplied by the number of Air Force CNG vehicles, 2,412 vehicles (see Equation 9). The amount of CNG consumed in 1999, 273,110 gges, reflects a reduction of 273,110 gallons of gasoline. The 273,110 gallons of gasoline were then subtracted from 581,292 gallons of gasoline to arrive at an adjusted amount (see Equation 10). This adjusted amount was then compared to amount of fuel that the Air

$$7.2 \text{ million gallons of gasoline} / 29{,}902 \text{ gasoline vehicles} = 241 \text{ gallons of gasoline} \tag{8}$$

$$(241 \text{ gallons of gasoline} \times 2{,}412 \text{ vehicles}) = 581{,}292 \text{ gallons of gasoline} \tag{9}$$

$$581{,}292 \text{ gal} - 273{,}110 \text{ gal} = 308{,}182 \text{ gal} \tag{10}$$
$$\text{gal} = \text{gallons of gasoline}$$

Force has to cut to meet E.O. 13149, which is 1,890,579 gallons based on 1999 consumption data from AFVSPO (see Equation 11). This analysis shows that if the Air

$$308{,}182 \text{ gal}/1{,}890{,}579 \text{ gal} = .16 \text{ percent} \tag{11}$$

Force used the CNG vehicles it already owns at the same average rate as conventional vehicles, the Air Force would need to cut 1,582,397 gallons instead of 1,890,579 gallons to meet the E.O. 13149 requirement (see Equation 12). This analysis was based on an

$$1{,}890{,}579 \text{ gal} - 308{,}182 \text{ gal} = 1{,}582{,}397 \text{ gal} \tag{12}$$
$$\text{gal} = \text{gallons of gasoline}$$

average usage rate, and did not consider the case where CNG vehicles are used on an above-average basis.

Analysis of the Air Force's CNG Vehicle Acquisition Policy

Analysis of whether the Air Force has optimized its use of funds in regard to its CNG acquisition policy was performed primarily through the use of two items. The first item was a 1998 AFCEE Report that addressed pollution prevention. The second item was the Air Force's 2000 CNG vehicle list, which breaks out whether a vehicle's CNG

equipment is OEM, converted, or dedicated. The AFCEE report considers three possible alternatives regarding AFVs (Air Force Center for Environmental Excellence, 2000b). The alternatives consider the acquisition of bi-fuel CNG vehicles or the conversion of gasoline vehicles to bi-fuel CNG vehicles. A table from the AFCEE report is reproduced as Table 12.

Table 12. Air Force Center Environmental Excellence Report Options

Options	**Labor Requirement**	**Equipment Requirement**
Status Quo (conventional fuel vehicles)	No additional.	No additional.
Alternative I (CNG Conversion on-base)	Conversion of vehicles by shop personnel.	CNG conversion kits. Fueling station.
Alternative II (CNG Conversion off-base)	Administration of conversion contract.	None. Equipment provided by off-base contractor. Fueling station.
Alternative III (purchase original CNG vehicles)	Selection of appropriate vehicles (comparable to selection of new conventional vehicles).	Fueling station.

(Air Force Center Environmental Excellence, 2000)

Capital cost assumptions listed in the AFCEE report are shown below (AFCEE:21):

General assumptions common to all alternatives:

CNG fueling station=$175,000. Based on fast fill station cost estimate from RP Publishing, Natural Gas Vehicles, May 1995.

Status Quo (conventional fuel vehicles)

Cost of gasoline powered vehicle = $15,000. Based on average estimated cost of light-duty gasoline vehicles

Alternative I (CNG conversions performed on-base)

CNG conversion kits = $1,500 each. Based on average cost of conversion kits for light-duty gasoline vehicles from survey of kit vendors.

Labor to perform conversion=20 hours per vehicle

Labor rate=$20/hour

Alternative II (CNG conversions performed off-base)
Contract CNG conversion=$2,500 each. Based on average cost of conversion of light-duty gasoline vehicle from survey of conversion companies.

Alternative III (purchase original CNG vehicles)
Original CNG vehicle=$25,000. Based on average cost of light-duty bi-fuel (CNG and gasoline) vehicle from major manufacturer.

The table in the AFCEE report that shows economic analysis is reproduced as Table 13. The analysis in the AFCEE report includes the cost of CNG infrastructure for the three options presented. If a unit already has access to CNG infrastructure and is considering setting up a CNG program, then the cost of infrastructure can excluded from the estimated cost of all three alternatives. The economic analysis suggests that on-base conversion may be the least expensive AFV alternative, given the Air Force's AFV policy to go mainly with CNG. This alternative does however require that base personnel get training on how to perform conversions and would entail down time for vehicles being converted. The off-base conversion option, while slightly more expensive, does not require additional training for base personnel and because a contractor is performing the work, manhours are not expended on converting vehicles. The off-base conversion option also allows Air Force units to get vehicles converted even when the base is experiencing a high operations tempo. The option that calls for the purchase of original CNG vehicles is considerably more expensive than the other alternatives, and may be a reason that only 20 percent of the Air Force's CNG fleet is OEM (Air Force Alternative

Fueled Vehicle System Program Office, 2000b). CNG and gasoline prices used in this table were based on 1998 fuel prices, and vary from the fuel prices stated earlier.

Table 13. Economic Analysis Reproduced from AFCEE Report

Cost Item	**Status Quo Conventional Fuel Vehicles**	**Alternative I CNG Conversions On-Base**	**Alternative II CNG Conversions Off-Base**	**Alternative III Purchase Original CNG Vehicles**
Capital Cost				
Fast fill CNG fueling station ($)		$ 175,000	$ 175,000	$ 175,000
Conventional Vehicles ($)		$ 15,000	$ 15,000	
Conversion Kit/ off-base conversion ($)	$ 15,000	$ 1,500	$ 2,500	
Original CNG vehicles ($)				$ 25,000
Number of Vehicles	10	10	10	10
Total Capital Cost ($)	$ 150,000	$ 340,000	$ 350,000	$ 425,000
Cost for the First Year				
Workhours per vehicle conversion (hr/vehicle)		20		
Labor rate ($/hr)	$ 20	$ 20	$ 20	$ 20
Number of vehicles		10		
Labor Cost ($)	$ -	$ 4,000	$ -	$ -
Unit cost of gasoline ($/gallon)	$ 1.10			
Unit cost of CNG gasoline equivalent ($/GEG)		$ .70	$ .70	$ .70
Qty of gasoline (or CNG GGE) required (gallons/yr)	5,000	5,000	5,000	5,000
Total annual fuel cost ($)	$ 5,500	$ 3,500	$ 3,500	$ 3,500
Total annual operating cost ($)	$ 5,500	$ 7,500	$ 3,500	$ 3,500
Total capital plus operating cost for the first year ($)	$ 155,500	$ 347,500	$ 353,500	$ 428,500

The payback periods and savings are not shown because these alternatives are not justified on strictly economic terms.

(Air Force Center Environmental Excellence, 2000)

Further analysis was performed regarding whether the Air Force has optimized its funds with its acquisitions of CNG vehicles. If all CNG vehicles that were procured OEM had been purchased as conventional fuel vehicles and converted after-market, then

for the same amount of money how many vehicles could have been converted? The data provided in Table 14 was used to answer this question. The number of CNG OM vehicles in the Air Force fleet was multiplied by the cost of equipping a vehicle with CNG equipment from the OEM, \$5,000, to arrive at the amount of CNG acquisition funds spent by the Air Force (see Equation 13). The amount of CNG acquisition funds spent to acquire the Air Force's 483 CNG OEM vehicles was then divided by the cost of an after-market CNG conversion, \$2,500 (see Equation 13). Given the same funding, and based on the aforementioned average costs, an additional 483 vehicles could have been converted. The data presented in Table 14 was based on average figures for the

Table 14. Possible CNG Vehicle Conversions

Air Force OEM CNG Vehicles	Avg Additional Cost of OEM CNG	Avg Cost of CNG after-market conversion	Possible number of vehicles that could have been converted
483	\$5000	\$2500	966

$$483 \text{ CNG OEM vehicles} \times \$5000/\$2500 = 966 \text{ vehicles} \quad (13)$$

additional cost of OEM CNG vehicles and the cost of an after-market conversion provided by AFVSPO personnel (Perazzola, 2000). This course of action, however is based solely on economic terms, and does not take into consideration whether the Air Force has enough eligible vehicles for after-market conversions nor does it take into consideration the availability of competent contractors to perform the conversions. It should be noted that unlike new CNG OEM vehicle acquisitions, which must be procured

via the pri-buy system, a vehicle already in the Air Force fleet can be converted in significantly less time. Although converting vehicles off-base is slightly more expensive than converting the vehicles on-base, the trade-offs involved make it the Air Force's most viable option.

Summary

The analysis conducted showed that while E.O. 13149 does have the potential of reducing oil imports, E.O. 13149's impact, if fully complied with would be minimal. The Air Force has drafted and forwarded a proposal to the DOE outlining its strategy for meeting E.O. 13149 requirements. Given that the Air Force must comply with E.O. 13149 and that the acquisition and use of AFVs is a primary strategy for meeting the E.O. requirements, the focus shifts to the Air Force's AFV policy. Analysis showed that the Air Force has concentrated efforts for meeting past environmental requirements on the acquisition and use of CNG vehicles. Analysis also showed that CNG has some attractive features that led to its selection by the Air Force as its primary alternative fuel, which would account for the increase of CNG vehicles in the Air Force fleet. Analysis regarding the Air Force's assignment of vehicles demonstrated that 61 of 74 Air Force units with CNG vehicles have access to CNG fueling infrastructure. Further analysis showed that a majority of the Air Force's CNG vehicles have been placed in or near MSAs, which can benefit significantly with the use of AFVs. The next area of analysis considered the extent that the Air Force's AFV policy might reduce emissions and increase alternative fuel use. The analysis was based on past performance in these areas. The analysis of reported usage showed that while the potential to substantially reduce

emissions and increase alternative fuel usage was there, it went largely unmet. The last area of analysis considered whether the Air Force had optimized its use of funds regarding its previous CNG acquisition policy. This analysis involved the use of an AFCEE report and the breakdown of Air Force CNG vehicles by type for 2000. The data showed that on-base conversion was the least expensive option and that the purchase of OEM CNG vehicles was the most expensive option. Further analysis demonstrated that if the Air Force had taken funds spent on more expensive OEM CNG vehicles and spent the same amount of funds on after-market conversions, then additional vehicles could have been converted to CNG.

Recommendations

When formulating policy, the Air Force takes into account a number of factors. Information from the areas of analysis has been compiled to provide a few recommendations regarding how the Air Force should modify its AFV program to meet E.O. 13149 requirements. Analysis regarding the limited contribution that increased AFV usage could provide to the Air Force in meeting E.O. 13149 requirements led to a recommendation that the Air Force should incorporate the five approaches provided by the DOE in its strategy to cut petroleum consumption. Analysis regarding the number of Air Force units that consumed little or no CNG in 1999 and 2000, and analysis regarding a decrease in the Air Force's CNG consumption from 1999 to 2000 despite an increase of 275 CNG vehicles to the Air Force's AFV fleet led to a recommendation that the Air Force should concentrate on increasing the usage of AFVs in their alternative fuel capacity. Analysis regarding the concentration of CNG vehicles in the Air Force's AFV

fleet and the fact that Air Force has CNG fueling infrastructure at 45 locations across the U.S. led to the recommendation that if the Air Force decides to acquire additional AFVs it should acquire CNG vehicles. Analysis regarding the cost advantage of converting vehicles to CNG after-market instead of acquiring vehicles with CNG equipment from the OEM led to the recommendation that if the Air Force decides to acquire additional CNG vehicles it should convert gasoline vehicles to bi-fuel CNG vehicles. Analysis regarding the cost advantage of converting vehicles to CNG after-market instead of acquiring vehicles with CNG equipment from the OEM, and analysis regarding the flexibility that off-base conversions offer led to a recommendation that if the Air Force decides to convert vehicles to bi-fuel CNG it should get the conversions performed off-base.

Conclusion

To determine how the Air Force should modify its AFV program to meet E.O. 13149 requirements, a series of questions had to be answered. The Air Force does intend to meet EO. 13149 and as such should incorporate the five approaches listed in the DOE's guidance on E.O. 13149. The Air Force should concentrate its efforts on increasing the usage of its AFVs in the AFV's alternative fuel capacity. If the Air Force does decide to acquire additional AFVs, CNG vehicles should be acquired. If the Air Force does decide to acquire CNG vehicles, it should have gasoline vehicles converted to bi-fuel CNG vehicles. If the Air Force does decide to convert vehicles to CNG, it should have the vehicles converted off-base.

V. Discussion

Managerial Implications

The recommendations provided, if implemented, could result in a number of managerial implications. The first area of concern involves the managerial implications of increasing AFV usage in the AFV's alternative fuel capacity. Analysis showed that the Air Force has not used its AFV capability to the same extent that it has used gasoline to power its vehicles. This lack of alternative fuel usage is contrary to the Air Force's existing policy as stated in Air Force Instruction AFI 24-301, Vehicle Operations (Department of the Air Force, 1998:93). The AFI states that "Air Force-owned or leased bi-fuel and flex fuel AFVs should be refueled with alternative fuels to the maximum extent possible" (Department of the Air Force, 1998:94). It appears that although the Air Force has had this usage policy in effect for a number of years, the Air Force's actual usage of AFVs has been substantially lower than the usage of its gasoline vehicles. Low alternative fuel usage is of concern because use of AFVs is one of the Air Force's primary strategies for complying with E.O. 13149. The Air Force's draft to the DOE regarding the Air Force's strategy for meeting E.O. 13149 requirements states that:

> MAJCOMs (Major Commands) shall utilize alternative fuels at least 50 percent of the time, when infrastructure availability warrants use. Establishing an Air Force 50 percent usage rate requirement of alternative fuels will contribute greatly to the reduction goal. (Air Force Alternative Fueled Vehicle System Program Office, 2001:1)

Air Force leadership has put forth this AFV usage policy because the usage of alternative fuel at least 50 % of the time is required by E.O. 13149, but unless this policy is effectively implemented and enforced, the policy will not produce the desired results.

The second area of concern involves the Air Force's ability to accomplish the goals put forth in its draft plan for meeting E.O. 13149 requirements. According to the draft plan, MAJCOMs are the Offices of Primary Responsibility (OPR) for many of the items listed (Air Force Alternative Fueled Vehicle System Program Office, 2001:1-6). To ensure that the Air Force is on course for meeting the 20 percent reduction by 2005, MAJCOMs should develop a program to track unit petroleum consumption. Tracking usage will help to highlight the importance of meeting E.O. 13149 requirements and will help to ensure that the Air Force can check its progress by receiving periodic reports from its MAJCOMS. MAJCOMs need to involve base transportation commanders in efforts to meet the 20 percent reduction goal. Base transportation commanders are responsible for maintaining the base's vehicle fleet and for ensuring compliance with AFI 24-301. The vehicle operations flight within the transportation squadron manages the base vehicle fleet. The vehicle operations flight's fleet management element trains unit Vehicle Control Officers (VCOs) and Vehicle Control Non-Commissioned Officers (VCNCOs), which manage the vehicle fleet of their respective unit. VCOs and VCNCOs are trained by fleet management and serve as the liaison between fleet management and the base personnel that actually drive and care for Air Force vehicles. If the Air Force is to increase CNG usage, there will have to be a fundamental shift in how AFVs are perceived by the airmen that use them everyday.

The third area of concern involves the standardization of off-base CNG conversions. If Air Force units opt to have gasoline vehicles converted by an off-base contractor, then the unit must coordinate with the Air Force Alternative Fueled Vehicle System Program Office to ensure that the contractor is reputable and capable of performing the conversion according to federal regulations.

Areas for Future Research

The Air Force's alternative fuel vehicle program must respond to changes in fuel and vehicle technology and changes in federal requirements regarding its vehicle fleet. In regard to the Air Force's AFV policy, the Air Force should explore cutting-edge technology so that it can shape policy instead of reacting to it. The Air Force may benefit from analysis performed in two areas of research. The first area of research entails analysis into the possible use of gas-electric hybrid vehicles. This area of research has been suggested due to the increasing availability of gas-electric hybrid vehicles and due to the fact that use of CNG is not considered a long-term solution. Research on whether the Air Force should incorporate hybrid vehicles into its fleet will be of benefit to the Air Force, because according to the Air Force's draft plan for meeting E.O. 13149 requirements, the Air Force is considering the use of hybrid vehicles (Air Force Alternative Fueled Vehicle System Program Office, 2001:2). Research might include and a comparison of the advantages and disadvantages of hybrid vehicles and a cost-benefit analysis of acquiring and using hybrid vehicles.

The second area of research entails analysis into where the Air Force's AFV program should be in ten years. Research into how the Air Force should transition its

predominantly CNG-based AFV program to meet future constraints and requirements will be of benefit to the Air Force. The AFVSPO is already considering options to adapt current technology for future use.

Conclusion

If the Air Force is to reduce its petroleum fuel consumption by 20 percent by 2005, it must get airmen at all levels to participate in its AFV program. Air Force leadership has developed a plan for meeting E.O. 13149 requirements; the next step is to effectively implement it.

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Air Force Institute of Technology
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14. ABSTRACT

The Air Force must comply with Executive Order (E.O.) 13149, which includes cutting its vehicle fleet's petroleum fuel usage 20 percent by 2005. This thesis examines the Air Force's current alternative fuel vehicle (AFV) program, which is centered around the acquisition and use of compressed natural gas (CNG) vehicles, to determine whether it has been effective, and how the AFV program should be tailored to contribute to the Air Force's efforts to comply with E.O. 13149. The results of the study discussed here suggest ways in which the Air Force's AFV program can be modified to increase the program's impact on petroleum consumption. Although analysis shows that full compliance by all federal agencies will decrease the annual amount of oil imported to the United States by less than one percent, the Air Force must meet E.O.13149 requirements. The Air Force has effectively managed its CNG vehicle fleet by assigning a vast majority of CNG vehicles to units with access to CNG fueling infrastructure, but usage of CNG vehicles' in their CNG capacity must be increased if the AFV program is to contribute to the Air Force's effort to cut petroleum usage.

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U	U	U	UU	82	**19b. TELEPHONE NUMBER** *(Include area code)* (937) 255-6565 x4283 William.Cunningham@afit.af.edu